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THE AMOCO CADIZ INCIDENT.

SITE VISITS SEVEN YEARS AFTER THE SPILL

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by

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June, 1985

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1. Introduction

The purpose of this study was to collect field data and oil/sediment samples in March, 1985 from the asphalt pavements that had reportedly formed in the aftermath of the Amoco Cadiz accident that occurred in March, 1978. The results will be used as a comparison with data collected from asphalt pavements studied as part of the shoreline component of the Baffin Island Oil Spill programme.

The objectives were to (a) collect samples from asphalt pavements that were known to have developed from the Amoco Cadiz Spill (as opposed to any of Tanio origin) and (b) attempt to determine why these pavements had formed. The samples have not been analysed as part of this study. This report describes the field observations and a more detailed interpretative report will be prepared after the sample analysis has been completed.

2. Summary of Observations

A total of eight sites were visited along the Brittany coast on 23rd and 24th March, 1985 (Figure 1). All sites were to the east of where the Amoco Cadiz ran aground and all had been heavily oiled during March and April, 1978. All but two sites provided examples of residual and persistent oil, but only one site (Toenot - a small harbour on the mainland adjacent to Ile Grande) exhibited an asphalt pavement as defined in Section 3. Oil was found to persist in areas above extreme tidal limits (SHWM), probably as a result of storm-wave activity. Oil was observed also in various locations in the upper and middle intertidal areas and with different sediment types and exposures.

At the Ile Grande marsh, oil was found within the sand and gravel sediments of the active streambed and drainage channels. The subsurface oil from Ile Grande marsh was very fresh and samples had a very strong smell of hydrocarbons; an oil sheen was easily raised during sample collection.

A wide range of weathering was exhibited by the samples. The most extensive asphalt pavement, at Toenot, had the most weathered oil. The surface of the pavement at this site was extremely hard and difficult to penetrate. The pavement did not exceed 3cm thickness at any observed part and samples were most easily collected at the edges. The pavement did not appear continuous through the area above the mean high water mark (MHWM) but buried portions of pavement were uncovered by scraping away the surface sediments. These buried pavements appeared somewhat less weathered and the surface could be easily scratched. In general, the pavement samples were very weathered and had no hydrocarbon aroma. No oil staining was observed and when mixed with water, no sheen was produced.

An oil mat was observed at several sheltered locations. This mat was coincident with fine-grained sediments and, unlike a pavement, was not mixed with sediment. Although extensive in area, this mat was often not immediately obvious from a distance due to vegetation growth through the oil cover.

3. Asphalt Pavement: What, Where and Why Do They Form

Asphalt pavements are well-weathered mixtures of hydrocarbons and sediments that, through time and physical changes, have formed a highly persistent and erosion-resistant deposit that is anchored onto the beach surface. The pavements may be exposed or buried and erosion usually takes place only along the edges.

Intertidal pavements have been observed to develop (1) in the zone between the mean high water mark (MHWM) and the spring high water mark (SHWM), (2) on well-drained substrates, not finer than medium-grain sand, (3) which have a low angle of inclination, (4) which are protected by some means or mechanism from strong physical forces, (5) do not exhibit a high ground-water table, and (6) where sufficient time permits weathering of the stranded oil.

(1) Oil laid down above the MHWM may only be covered by water during high tides on 10 or 15 occasions each month. This inundation depends upon

the width of the beach and the tidal range. Any oil in this zone is therefore not as exposed to the eroding effects of water washing over the surface as oil that is stranded below the MHWM.

(2) The pavements are well anchored into the beach. Well-drained sediments, which are permeable, allow viscous oils to penetrate the upper layer of beach sediments and thereby become incorporated into the sediment. Initially the surface oil that had not penetrated the sediments would serve to protect the developing pavement mixture. As the surface oil is removed the emerging asphalt pavement would be more resistant to erosion and weathering. If the sediments are too fine or the oil too viscous, thus preventing penetration, then the oil could be more easily removed even by infrequent or low-energy tidal or wave forces. A pavement can only form on a sand beach if the oil can penetrate into the surface sediments, whereas on a pebble beach virtually all oils can migrate through interstitial spaces. In the latter case an oil must have some internal cohesion or it will migrate below the surface and an insufficient volume will remain on the surface to form a pavement.

(3) The angle of inclination of the beach or beach face will affect the residence time of oil on the surface and hence the potential for oil penetration. Also water tends to run quicker over steeper surfaces, which would result in more energetic physical forces coming in contact with stranded oil.

(4) One of the most important components in creating the time for the pavement to form is protection from high-energy forces. Wide, gently sloping beaches that limit wave height on the beach face or physical obstacles that reduce fetch both tend to increase the time that the oil remains on the sediments, which in turn increases penetration potential and subsequently surface weathering.

(5) High ground-water tables would act as a barrier to oil penetration of beach sediments and in extreme cases, if the surface sediments are wet, this would reduce the opportunity for oil to remain and penetrate.

In spite of the importance of the presence of oil in a low-energy or protected environment, an asphalt pavement will not be produced if the other conditions are not met. As an example, at two sites visited during the survey a very thin oil layer, similar to a latex mat (Photo 6), covered the sediments. The asphalt pavement is a very different feature when compared to those sediments that have the thin 'mat' covering. The mats were seen at Croix and Ile Grande in the low-energy mud flats and marsh environments respectively. There is no indication at either site of oil penetration into the sediments and the coverage is continuous from the extreme upper intertidal (SHWM) through the MHWM and as low as the Neap High Water Mark (NHWM). These mats completely covered large areas and vegetation was reported to have only recently begun to penetrate these sites. The texture of the mats was quite rubbery and somewhat malleable in direct contrast to the pavements which were hard, dry and brittle.

The interpretative report will include a discussion on how these observations relate to reported data from other spills such as the Metula and Arrow.

4. Summary of Site Visits

Eight sites between Portsall and Ile Grande (Figure 1) were visited to determine if asphalt pavements had been deposited in any of a wide range of wave-energy and tidal environments on this coast. Other aspects of the effects of the spill were evident. Many of these observations are noted here and 35 samples were collected in the event that funding could be arranged for total hydrocarbon (th) and gas chromatographic (GC) analyses. Briefly the 8 sites were:

A. Treompon - a wide, sandy beach backed by sand dunes

B. Aber Benoit: near Loc Majan - a narrow short bay with a sandy, pebble-cobble intertidal zone; wet with moderate slope angle

C. Aber Benoit: Croix - mud flats on two levels; the upper level is flat or low angle (schorre), the lower level (slikke) gently sloping or steep; the upper level is considerably more trafficable than lower level

D. Ile Toenot - a sand-pebble environment backed and underlain by bedrock and fronted by a shallow well-protected bay

E. Ile Grande marsh - a marsh presently undergoing sand invasion as a result of clean-up operations; a complex area that is still recovering from the oil spill.

F. Ile Grande: Pointe de Toul-ar-Staon - a high-energy bedrock platform and boulder beach backed by a very large and high-energy cobble beach that rises steeply to the storm ridge crest; the steep beach face is on the order of 20 m high.

G. St. Michel en Greves - an extremely wide beach, up to 2 km, backed by a sea-wall

H. St. Marguerite - wide, fine and medium-grained sands with extensive sand-dune environment in the backshore

Site A - Treompon

This location was the closest of the areas visited to the site of the grounding of the Amoco Cadiz. Oil had been reported to be buried within the beach and on the faces of the dunes. Pits were dug at two locations but no oil was detected prior to encountering the water-table. There was no oil visible on the beach and local farmers were hauling seaweed away for use as fertilizer (Photo 1). A map of the area and a brief 1979 site description with beach profiles is included in Appendix C. The site visited in this study is marked by a cross on page C-1. No samples were collected at this site.

Site B - Aber Benoit (Loc Majan)

The Aber Benoit is a tidal estuary and Site B was located several kilometres inland at the head of a small, narrow bay on the south shore near Loc Majan (Figures 1 and 2A).

The site is similar in physical character to Profile A on page C-4. Two types of oil deposits were noted, neither of which was extensive. The first type was found at the SHWM and was similar to other oil 'mat' materials found later at Croix and the Ile Grande marsh. Only several small patches were found, several centimetres in diameter. Sample #1 was taken at this location. Nearby at the NHWM, a second small deposit was located (Photo 2). This material formed a very thin layer over the sediments and Sample #2 was collected at this location. Both samples from this site were dry and did not smell of hydrocarbons.

Site C - Aber Benoit (Croix)

The location of Site C was further inland near Croix. Vandermeulen and Long have established two transects here for sedimentology studies. We collected our samples along these transects (Figure 2A). The area is typically a mud flat area which has two primary zones (Photo 4).

The lower half of the intertidal zone (slikke) extends to the MHWM (Figures 2B and 2C); this zone is very wet and supports extensive algae growth (Photo 7). When these algae pads were removed a large amount of black material was uncovered (Photo 8) which may be degraded biological matter. A sample (#6) was collected from this site for analysis.

The upper beach (schorre) is only covered by the high tides (Photos 3 and 5). The entire upper beach shorezone from the SHWM to the MHWM is covered by a mat of oil. The mat is quite thin (1.0 to 2.0 cm) but is reasonably malleable, and is very similar to a latex covering (Photo 6). The mat has created a surface cover on the marsh which has only recently been penetrated by the vegetation. Surface samples were

collected in this zone on the two transects (Figure 2A). There did not appear to be any oil penetration into the sediments but subsurface samples (#4 and #5) were collected along one transect. A layer of dead plant matter was evident immediately below the oil mat. This layer adhered to the underside of the oil samples that were collected from the upper beach. It is believed that this organic layer represents vegetation that was smothered following the stranding of the oil mat. We are also attempting to identify the emerging vegetation to compare with other spill information.

A total of five samples were collected; there was no visible oil apart from the surface mat.

Site D - Toenot

Toenot is a small harbour on the mainland across from Ile Grande. Site D was located around a rocky headland immediately to the west of the entrance to the small boat harbour (Figures 3A and 3D). The asphalt pavements were very thin, in the range of 1 to 3 cm and located above the MHWM and below the SHWM (Photo 11). The pavement was not continuous at first glance but further investigation revealed that the pavement extended under the sand cover. Without removing all of the sand we could not determine if the pavement was continuous but several test holes and scraping did reveal the pavement under a thin veneer of sand. The pavement found under the sand was not as weathered as the exposed oil, but did not smell of hydrocarbons nor have an oily residue upon contact.

At one site a surface sample (#34) of the pavement was collected which did contain detectable traces of aromatic hydrocarbons. At this location the pavement was 3 cm in depth but effort was still required effort to collect the sample.

The beach above the MHWM consisted of medium to coarse grain sand with small cobbles. The intertidal beach is quite extensive as the harbour and marsh have a large draining area. In addition, the entire area is protected by natural rock barriers which limit the fetch to about 3 km.

A total of four samples were collected at this site (Figure 3D). The site with evidence of fresh hydrocarbons was sampled as were three representative sites across the beach from varying heights in the zone between the MHWM and SHWM.

Site E - Ile Grande Marsh

The Ile Grande marsh is located on the western side of the bridge/ culvert on the road that joins Ile Grande to the mainland (Figure 3A). This site best illustrates the long-term effects of the Amoco Cadiz spill in several aspects. As a result of the spill and the clean-up operations much of the marsh has been exposed to increased erosion after the surface vegetation cover (Juncus) was oiled, trampled or removed. Sand sediments are encroaching on the marsh and gradually covering some degraded sections. At the furthest encroachment of the sand there is a 3-5 cm thick layer of dried material, coloured like weathered oil, that is very granular in nature and that overlaps the marsh sediments and surrounds the Juncus roots. A sample of this material was collected (#9). As the survey was conducted in winter and the vegetation was not growing it is difficult to determine the viability of vegetation at the fringe, but in many sections the surface sediments and vegetation have been dramatically undercut (e.g. at Location 1 on Figure 3B: Photo 15).

Areas within the new sand ripple zone on the south side of the marsh (Location 3: Figure 3B) contained oiled sediments, which may have been asphalt pavement remnants (Photo 27) and samples were collected at several elevations from the MHWM to the landward edge (Photos 28, 29 and 30). These were sampled at the surface and subsurface levels (Figure 3C). No fresh hydrocarbons were encountered at this site. Physical barriers have been erected to prevent the sand from completely invading the marsh, in particular around a private residence and in the more mature areas of the marsh. The upper sample (#13) was collected immediately in front of these structures. To the west of Site 3 is a beach (Location 4) very similar to that at Toenot.

Pavements, or at least deteriorated pavements, were evident here and surface samples at four sites were collected (#17 to 20: Figure 3C). One of these samples (#19) was collected when some 'pure' oil was discovered in blobs on several sites. Analysis will determine if this is Amoco Cadiz oil or more recent material.

In the centre of the marsh on the south side of the main channel (Locations 6 and 7: Figure 3B), the effects of erosion caused by clean-up operations are most evident. The channels that were dug to drain the surface pools of oil have eroded. Even the tributary channels which lead to the main channel are showing signs of active erosion, slumping and overhanging edges with exposed vegetation and with new sediments deposited to the sides of the channel. Vehicle tracks are still evident at several locations and photographs from this study (Photos 24, 25 and 26) may be compared with those on page 175 in Berne and D'Ozouville (1979).

Samples collected on one of the major tributory channels, below water level at low tide, contained very fresh oil which left large dull coloured stains (Photos 22 and 23) and an extremely strong aromatic smell upon removal (#21 and #22). A sample collected from the bottom of the main stream draining the marsh (#10) (and separating the north and south sides of the marsh - Photo 19) also contained fresh hydrocarbons and released a visible dull sheen to the water's surface. In both cases the oily sediments were overlain by fine sediments topped with coarse sand and gravel materials.

As previously noted the 'latex mats' were found at Ile Grande. Although the latex mats were found on both sides of the marsh, samples from the surface and subsurface were collected only from the north side of the marsh (Location 8). Samples of the surface mat and two levels of subsurface sediments were collected at this site from the marsh flat, the berm of the creek channel (only one subsurface sample) and the lower slope of the creek channel.

Revegetation of the tributary channels had been attempted to a limited degree and appears to be taking hold. The oil mat, although providing a stable and hard surface, does not appear to halt the erosion process as it is easily undercut by eroding forces.

Twenty-two samples were collected from the marsh environment. Most of these samples are not related to actual asphalt pavements but are representative of the long-term impacts of oil on low-energy environments.

Site F - Ile Grande - Pointe de Toul-ar-Staon

Ile Grande was also the location of Site F. This high-energy boulder/large cobble beach is located on the north shore of Ile Grande and is as exposed to the full force of wave activity as any on this section of French coastline. The elevation difference from the low-tide level to the upper limits of the cobble beach is on the order of 20 m (Photos 37 and 38).

Oil residue deposits were located at the upper limit of the cobble beach (Photos 37 and 39). These were likely placed there by storm activity during spring tides. The deposits were not continuous but restricted to discreet pockets along the upper margins of the cobble beach. One sample (#32) was collected along the upper-margin from deposits located among the large cobbles. There was no evidence of oil in the lower portions of the beach; although black algae on the rock gave the impression of oil contamination even from several yards distance. It is unlikely that any oil could persist in this high-energy environment in the zone of wave activity and it is only above the intertidal zone that any is still evident.

Site G - St. Michel en Greves

St. Michel en Treves has an extensive beach extending for 1.5 to 2.0 km from a man-made sea wall that is fronted by a cobble berm (Photo 40). This beach was extensively oiled during the spill incident and about twelve hours after the oil hit the shore up to 30 x 10^6 organisms were driven out of the sediments and died on the surface (see Photos 4-4, 4-5 and 4-6 on pages P-17 and P-18 in Hess, 1978).

No evidence of residual oil was detected and it was apparent that this beach had not suffered from long-term effects of the spill. This could be in part due to the wide intertidal area high-water table and fine sand composition of the beach (Photo 41).

Site H - Presqu'ile Ste-Marguerite

This location was visited in the area of station F37 indicated on page C-5. Asphalt pavements were observed in 1979 and the site had been visited by various investigators since that time. No evidence of buried or exposed oil was found but a sample was collected (#8) to determine if any residual hydrocarbons remain in the sediments.

5. Comments

As part of a series of investigations for spills on the Brittany coast, field investigations were conducted to define sections of shore where oil had remained from the Amoco Cadiz spill. Based on surveys conducted by CEDRE in 1984 to delineate contaminated shorelines a brief field survey was designed to collect sediment samples that might represent stranded oil that remains in 1978, seven years after the spill incident.

The definition and the criteria for asphalt pavement development given in Section 3 were developed from observations made in this study, at the BIOS experiments, and following the Arrow spill. It is evident that an asphalt pavement can form only when a particular set of

environmental and spill conditions coincide. Asphalt pavements are not common despite the resistance of pavements to erosion by physical forces. However, where they are found they may persist for decades. Those visited in 1982 in Chedabucto Bay, Nova Scotia, following the Arrow Spill were formed in 1970.

No data on the chemical properties of oil in an asphalt pavement has been obtained other than that from the BIOS Project. The results from this study will provide a comparable data set that may provide insight into how and why a pavement forms.

A new item of information obtained from this study is that a surface mat of oil can and does remain in the upper tidal zone after seven years in protected sites. This mat, or 'latex-type' cover, is different from a pavement as the oil rests on the sediment surface and contains no incorporated sediments. This mat was found to occur only with fine-grained (i.e. closely packed) sediments and it is likely that the same oil type may form a mat cover on fine sediments and an asphalt pavement on coarse sediments. Geochemical analyses of the samples may provide more data on this hypothesis.

6. Acknowledgements

The study was funded by Environment Canada and was made possible by the supportive efforts of G. Sergy (EPS - Edmonton).

M. Jacques Denis (CEDRE - Brest) supported the project from its inception and provided data from unpublished sources regarding the most suitable sites to visit during our short field visit.

Dr. Bernard Long (INRS - Rimouski: on sabbatical at CNEXO - Brest) accompanied us on the site visits and provided considerable personal knowledge and information concerning the history of oiling and clean-up/recovery at each location.

7. References

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APPENDIX A - SAMPLE LIST

Sample No.	Site/Location (see Figures 1, 2 and 3)	th/GC	
1	B	GC	SHWM - 'latex' layer
2	B	th/GC	NHWM - 1.0 m below #1
3	C	GC	MHWM - 'latex' layer
4	C	(GC)	At #3 MHWM - 0 to 2 cm
5	C	th/GC	At #3 MHWM - 2 cm to 8 cm
6	C	th	Algae below NHWM
7	C	(GC)	MHWM - Station II
8	H	(th)	
9	E-1	th/GC	NHWM
10	E-2	GC	Near LWM: creek channel
11	E-3	GC	1.0 below SHWM - sandy; hard asphalt
12	E-3	th/GC	0.5 below SWHM - sandy; hard asphalt
13	E-3	GC	SHWM - cobble; hard asphalt
14	E-3	th	Background sand sample from base of mobile sand at 3.0 to 4.0 cm
15	E-3	th	Same site as #12: composite from top 5 cm (sandy-silt)
16	E-4	th	1.0 m below SHWM - sandy asphalt
17	E-5	GC	SHWM
18	E-5	th	SHWM
19	E-5	GC	tar; crystalline, thin, shiny (not asphalt)
20	E-4	th	SHWM
21	E-5	(hold)	Channel edge at LWL
22	E-5	GC	Channel edge at LWL
23	E-8	GC	Marsh surface 0 - 1.0 cm
24	E-8	th	Surface 0 - 1 cm: 0.25 m elevation below #23
25	E-8	th	At #24: 5-10 cm depth below oil layer

26	E-8	th	2.0 m below #23: top 2 cm
27	E-8	th	2 - 5 cm depth at #26
28	E-8	th	5 - 10 cm depth at #26
29	E-8	th	1.0 - 3.0 cm at #23
31	E-8	th	3.0 - 8.0 cm at #23
32	F	(hold)	High energy pebble/cobble/oil matrix at storm-ridge crest
33	D	th	1.0 m below SHWM
34	D	GC	'Fresh' oil - 1.0 m below SHWM
35	D	th	1.0 m below SHWM
36	D	th/GC	1.0 m below SHWM

Notes: (a) Sample #30 was not collected

(b) 20 samples are intended for t-h analysis and 15 for GC analysis; plus five 'optional' samples

APPENDIX B - MAPS AND FIGURES

Figure No.		Reference
1	General Area and Location of Field Sites	+
2A	Aber Benoit: Location Map and Sample Sites	*
2B	Aber Benoit: Profile at Croix Site 1	*
2C	Aber Benoit: Profile at Croix Site 11	*
3A	Ile Grande: Location Map	o
3B	Ile Grande: Marsh Site Locations	o
3C	Ile Grande: Marsh Sample Locations	o
3D	Ile Grande: Toenot Sample Locations	o

References

+ Berne and D'Ozouville (1979)

o Vandermeulen, Long and D'Ozouville (1981)

* Vandermeulen and Long (in press)

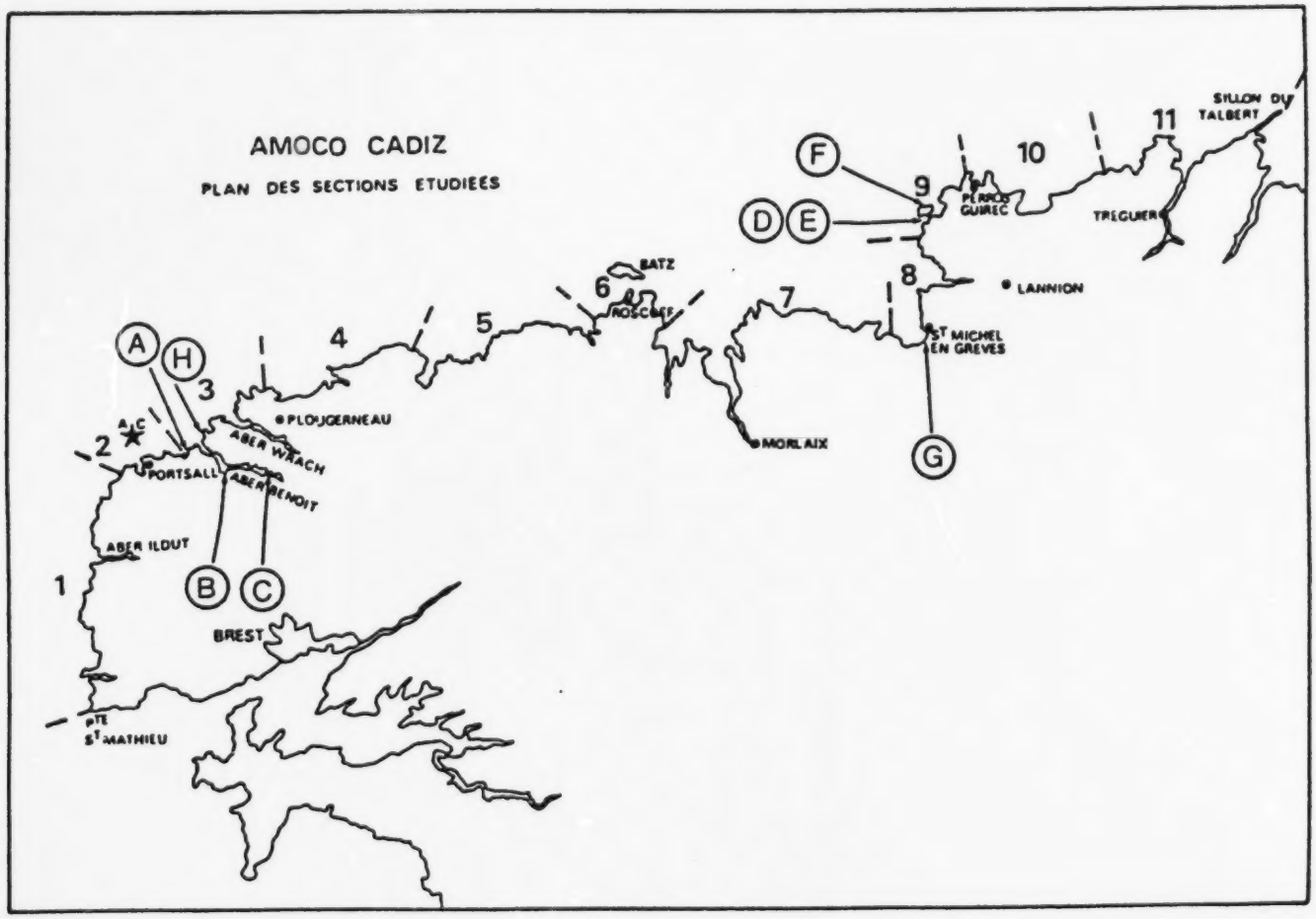

AMOCO CADIZ
PLAN DES SECTIONS ETUDIEES
A
H
B
C
D
E
F
G
1
2
3
4
5
6
7
8
9
10
11
A/C
PORTSALL
ABER ILDUT
ABER WRACH
ABER BENOIT
PLOUGERNEAU
BATZ
ROSCOFF
MORLAIX
LANNION
ST MICHEL EN GREVES
PERROS GUIREC
TREGUIER
SILLON DU TALBERT
BREST
PTE ST MATHIEU

Fig 1

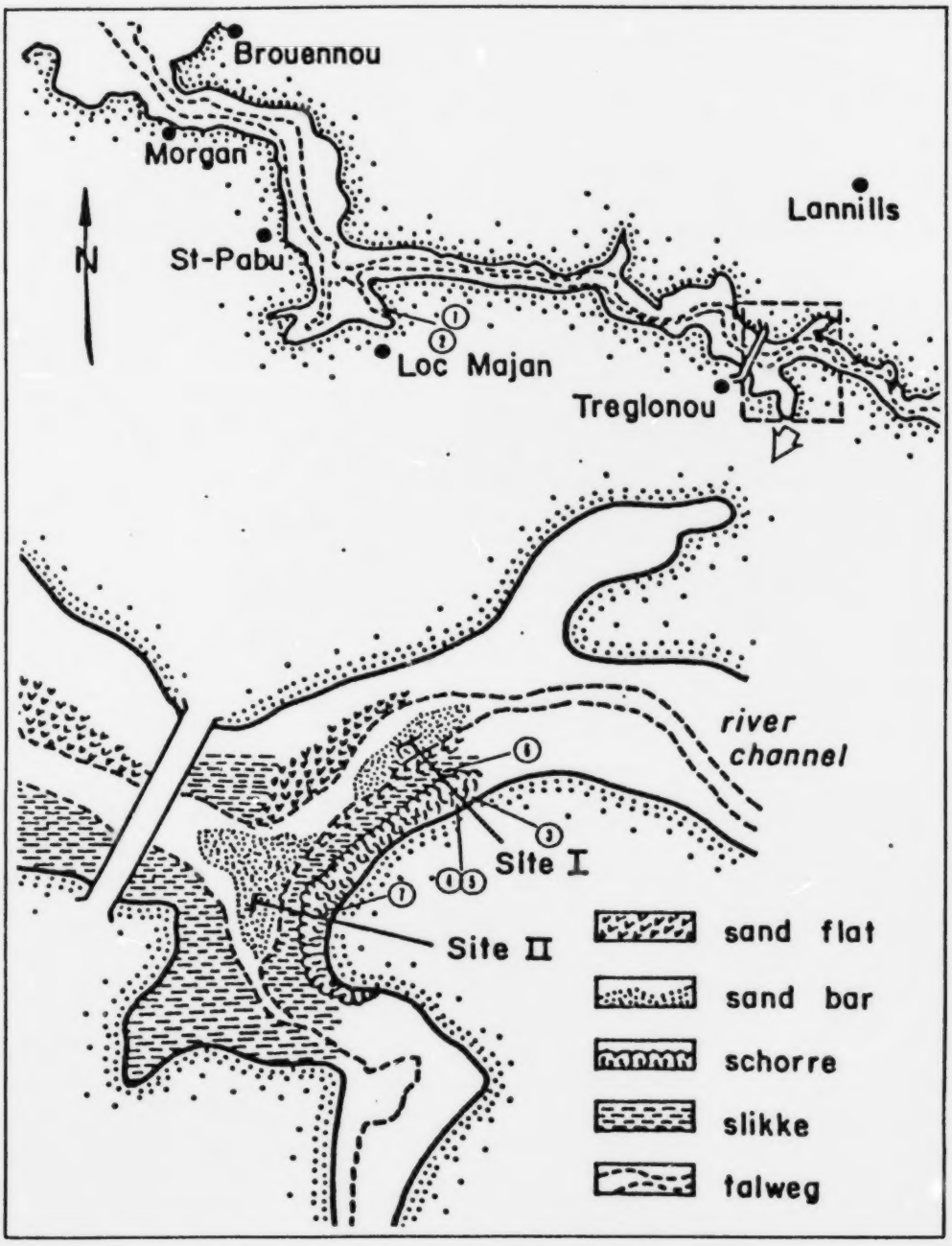

Brouennou
Morgan
N
St-Pabu
Lannilis
Loc Majan
Treglonou
river channel
Site I
Site II
sand flat
sand bar
schorre
slikke
talweg

Fig 2A

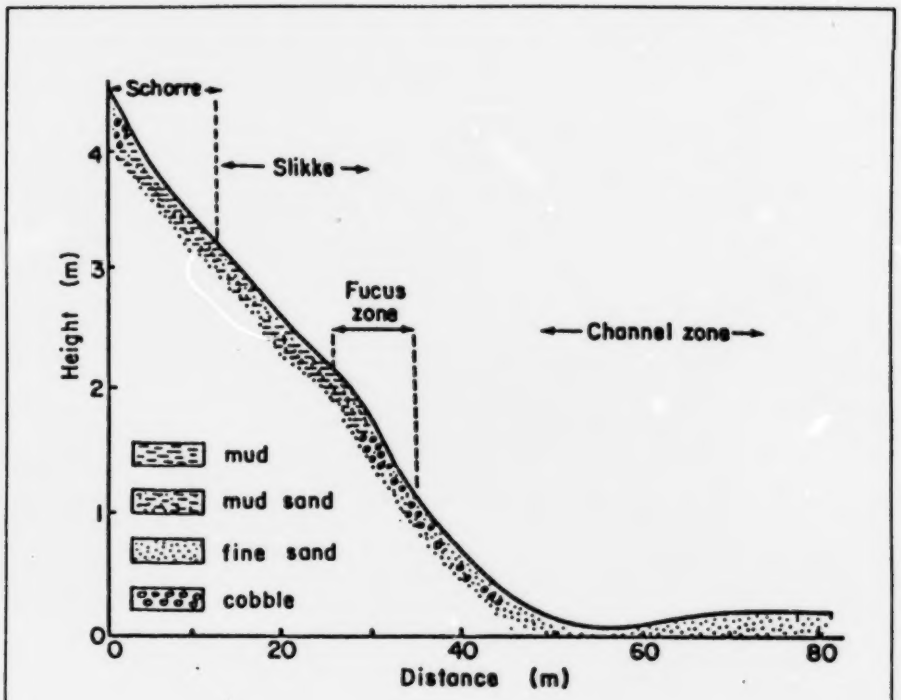

Schorre
Slikke
Fucus zone
Channel zone
Height (m)
0
1
2
3
4
mud
mud sand
fine sand
cobble
0
20
40
60
80
Distance (m)

Fig 2B

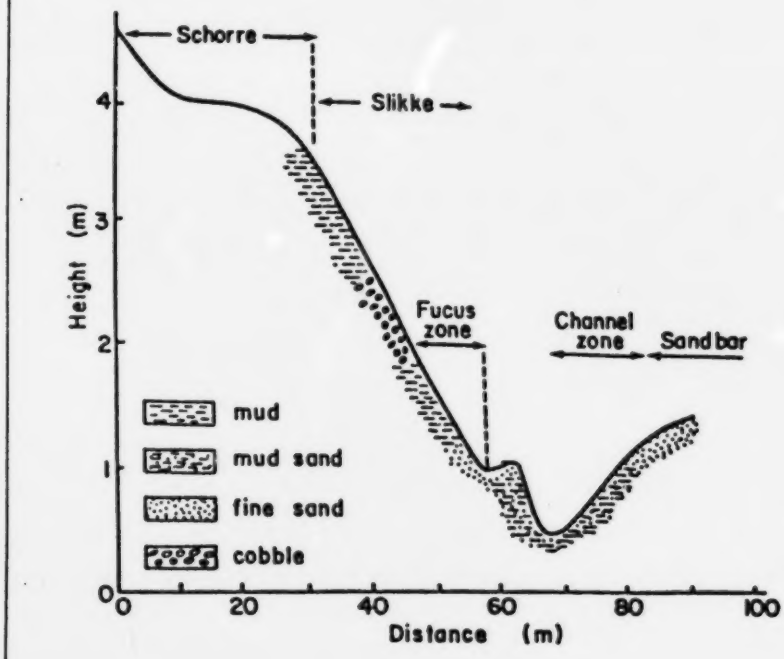

Schorre
Slikke
Fucus zone
Channel zone
Sand bar
Height (m)
0
1
2
3
4
mud
mud sand
fine sand
cobble
0
20
40
60
80
100
Distance (m)

Fig 2C

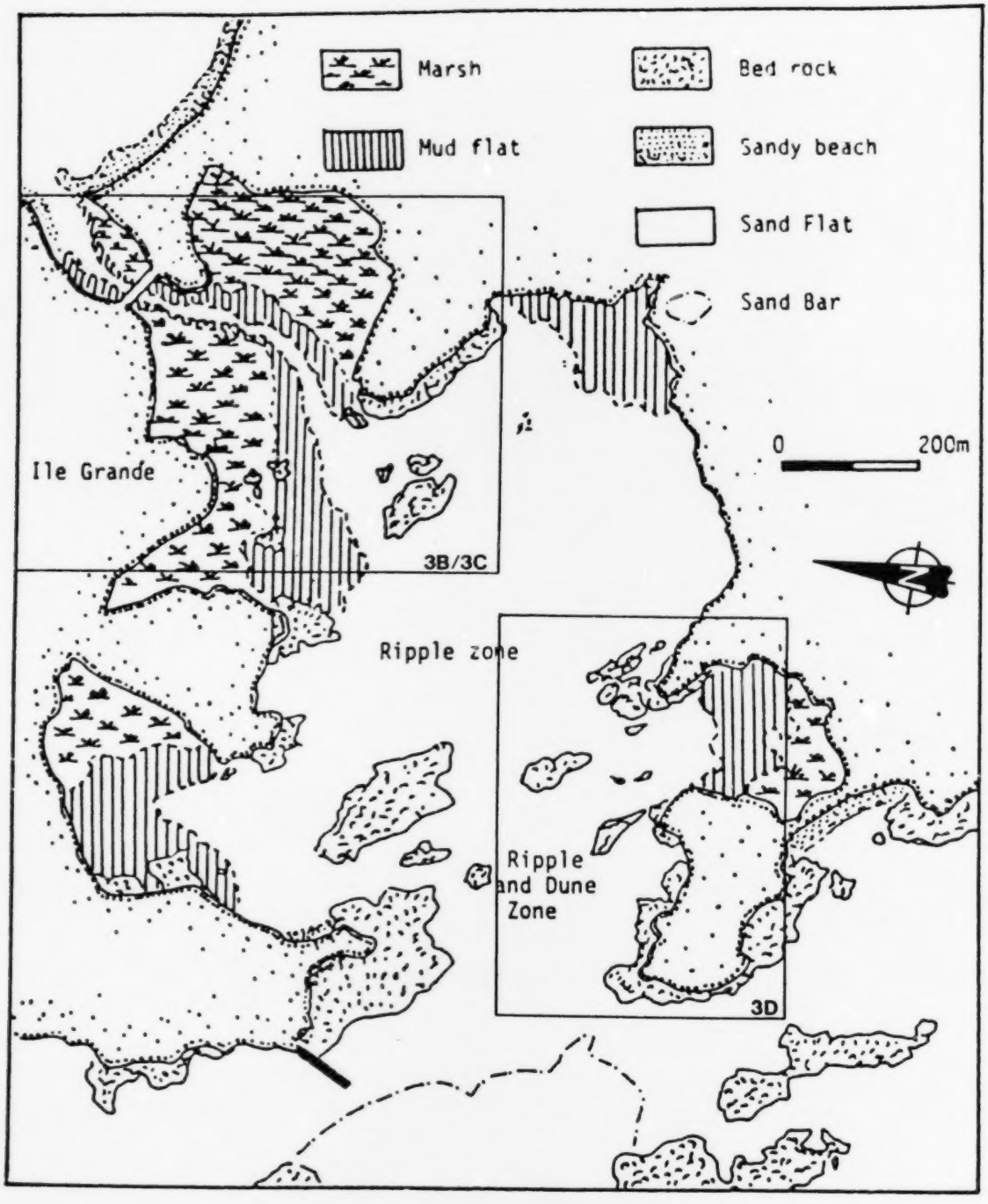

Marsh
Bed rock
Mud flat
Sandy beach
Sand Flat
Sand Bar
0
200m
Ile Grande
3B/3C
N
Ripple zone
Ripple
and Dune
Zone
3D

Fig 3A

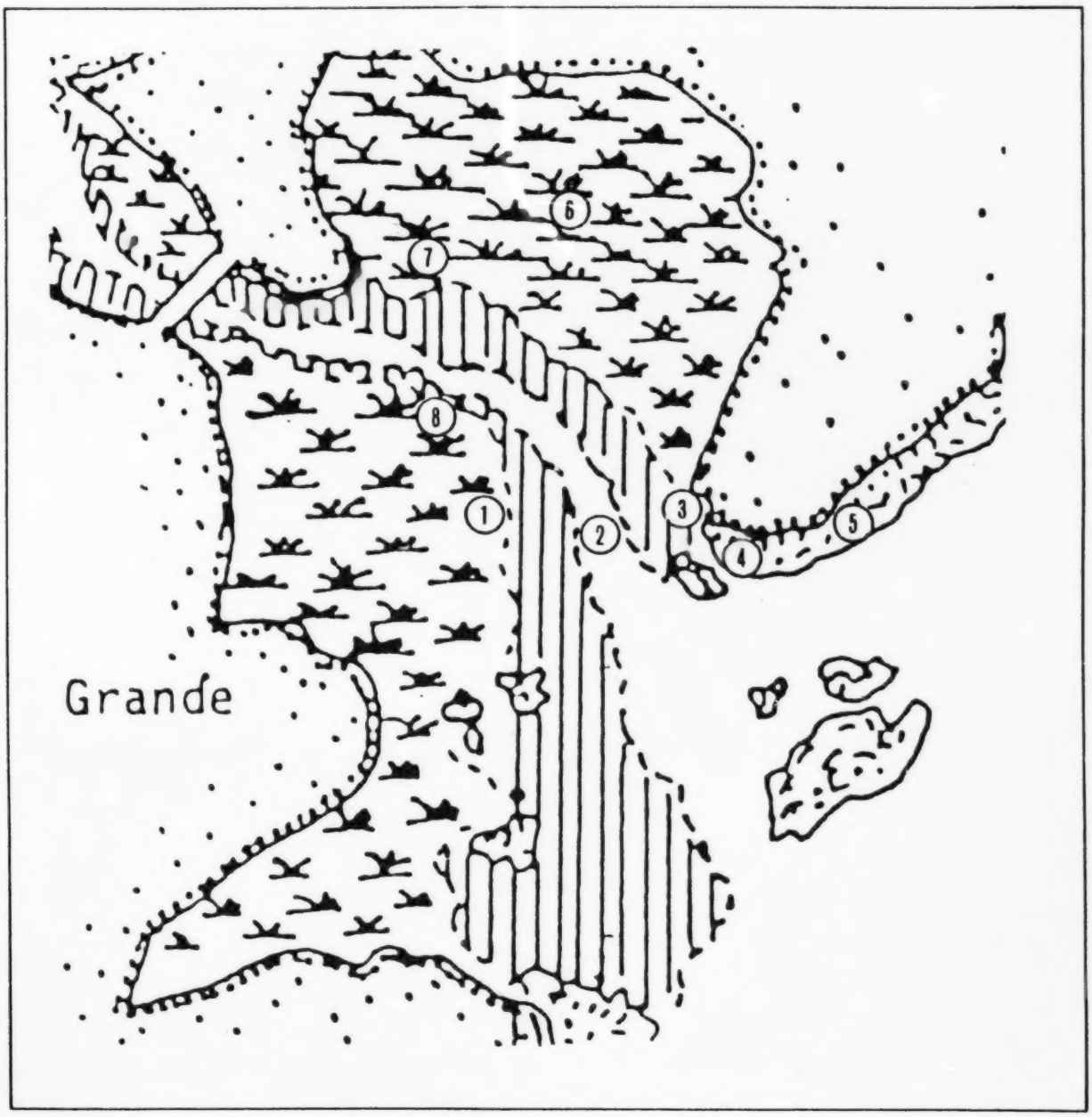


Fig 3B

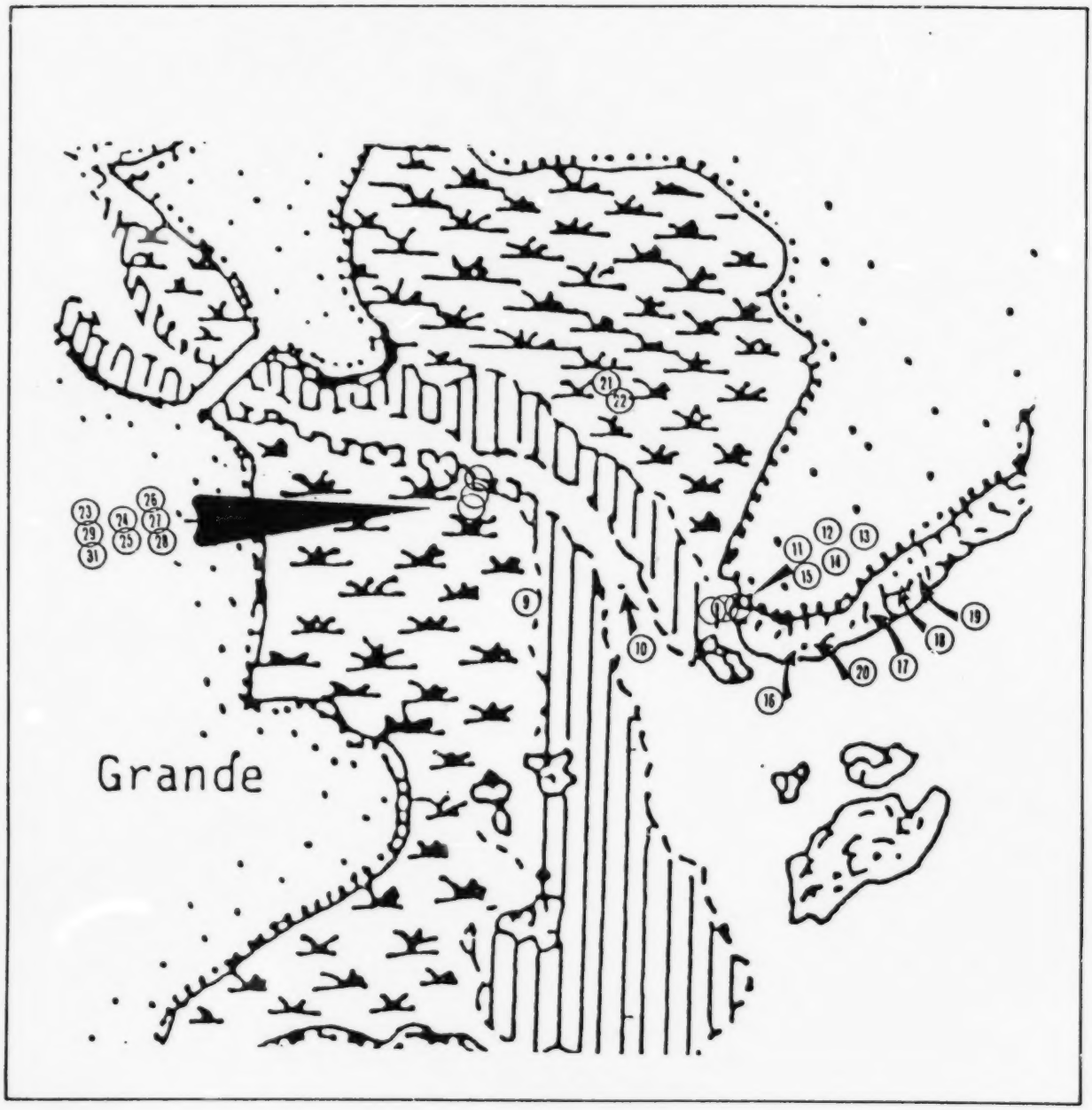


Fig 3C

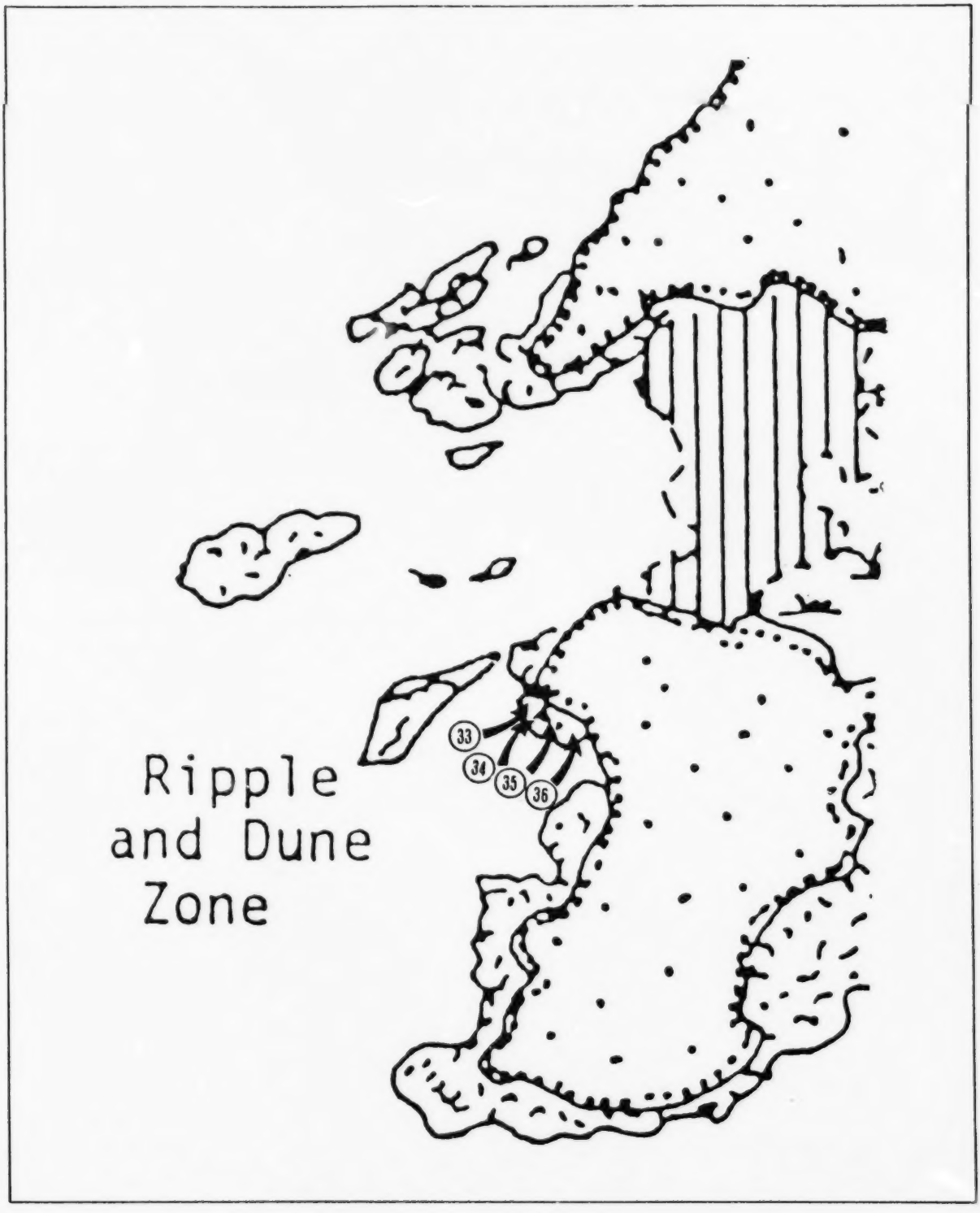


Fig 3D

APPENDIX C - SITE DESCRIPTIONS FROM PREVIOUS STUDIES

Page	Site	Description	Reference
C-1	Treompon: (A)	Location Map	+
C-2	Treompon: (A)	Site Description AMC 5	+
C-3	Treompon: (A)	Beach Profile at AMC 5	+
C-4	Aber Benoit: (B)	Beach Profiles at Loc Majan ('A' on this figure)	o
C-5	Ste-Marguerite: (H)	Location Map	+
C-6	Ste-Marguerite: (H)	Site Description F 38	+
C-7	Ste-Marguerite: (H)	Site Description AMC 11/F 37	+
C-8	Ste-Marguerite: (H)	Beach Profile AMC 11	+
C-9	Ste-Marguerite: (H)	Site Descriptions F 37/F 38/AMC 11	o
C-10	St. Michel En Greves: (G)	Site Descriptions AMC 15/AMC 19	+
C-11	Ile Grande: (D, E, F)	Location Map	o
C-12	Ile Grande: (D)	Site Descriptions F 135/AMC 18	+
C-13	Ile Grande: (D, F)	Site Descriptions F 76/F 135/AMC 18	o
C-14	Ile Grande: (F)	Site Description F 76	+

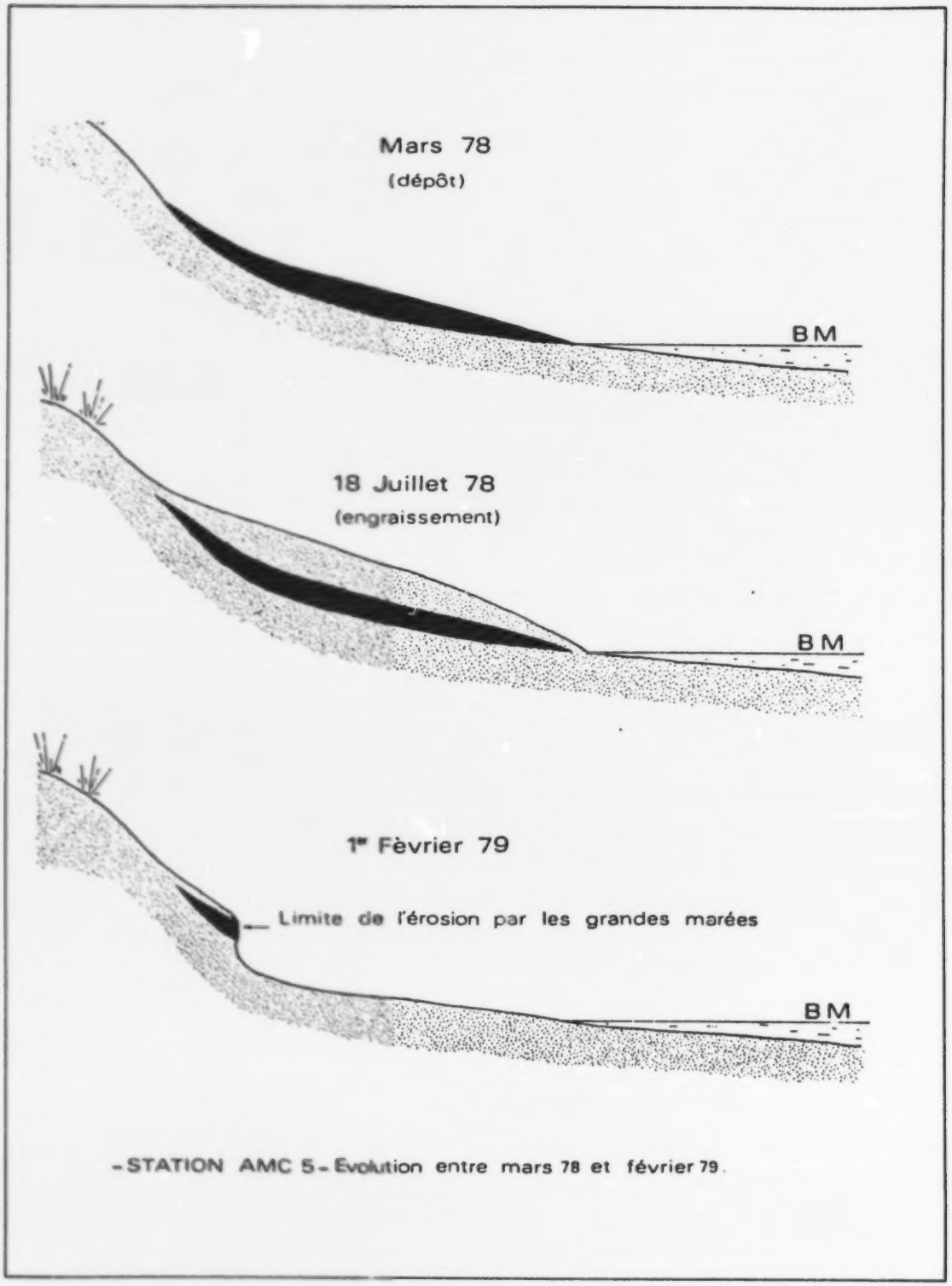
References

+ Berne and D'Ozouville (1979)

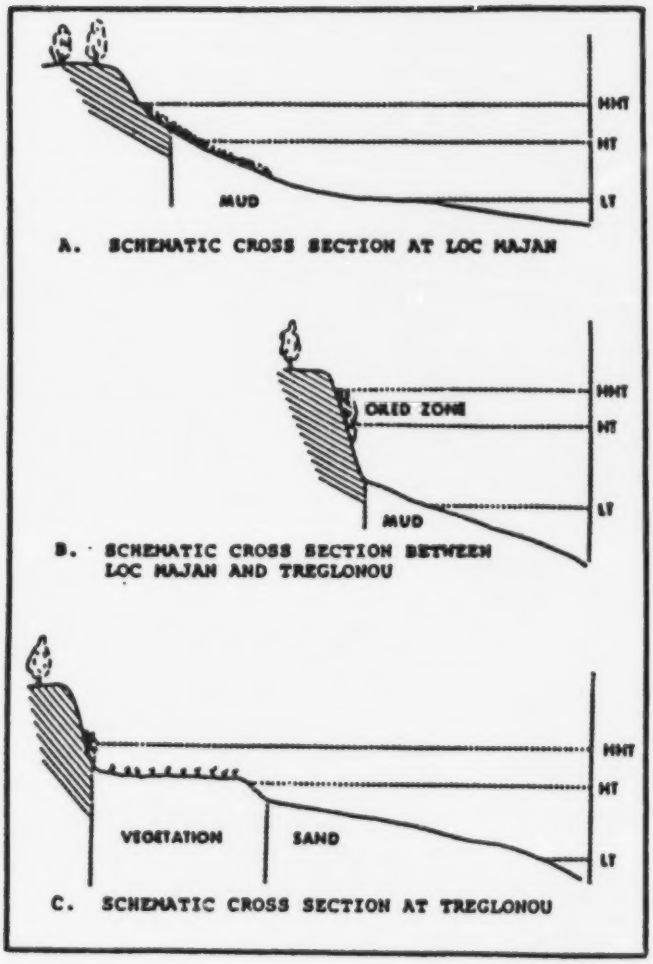
o Hess (1978)

AMC 5
Roc'h ar Sarpant
X
Lestevenn
Ruscalet
Trémpan
la Flasque
Kervao
Créer Dibenn
Lampaul
Ploudalmézeau
Kergounan
Ty Cam
Kerhigo
Kelou Mad
Kerléoch
Kergonan
Corn ar Gazel
Gopeledgau
Merrn
ECHELLE : 1/25 000
SECTION : 2

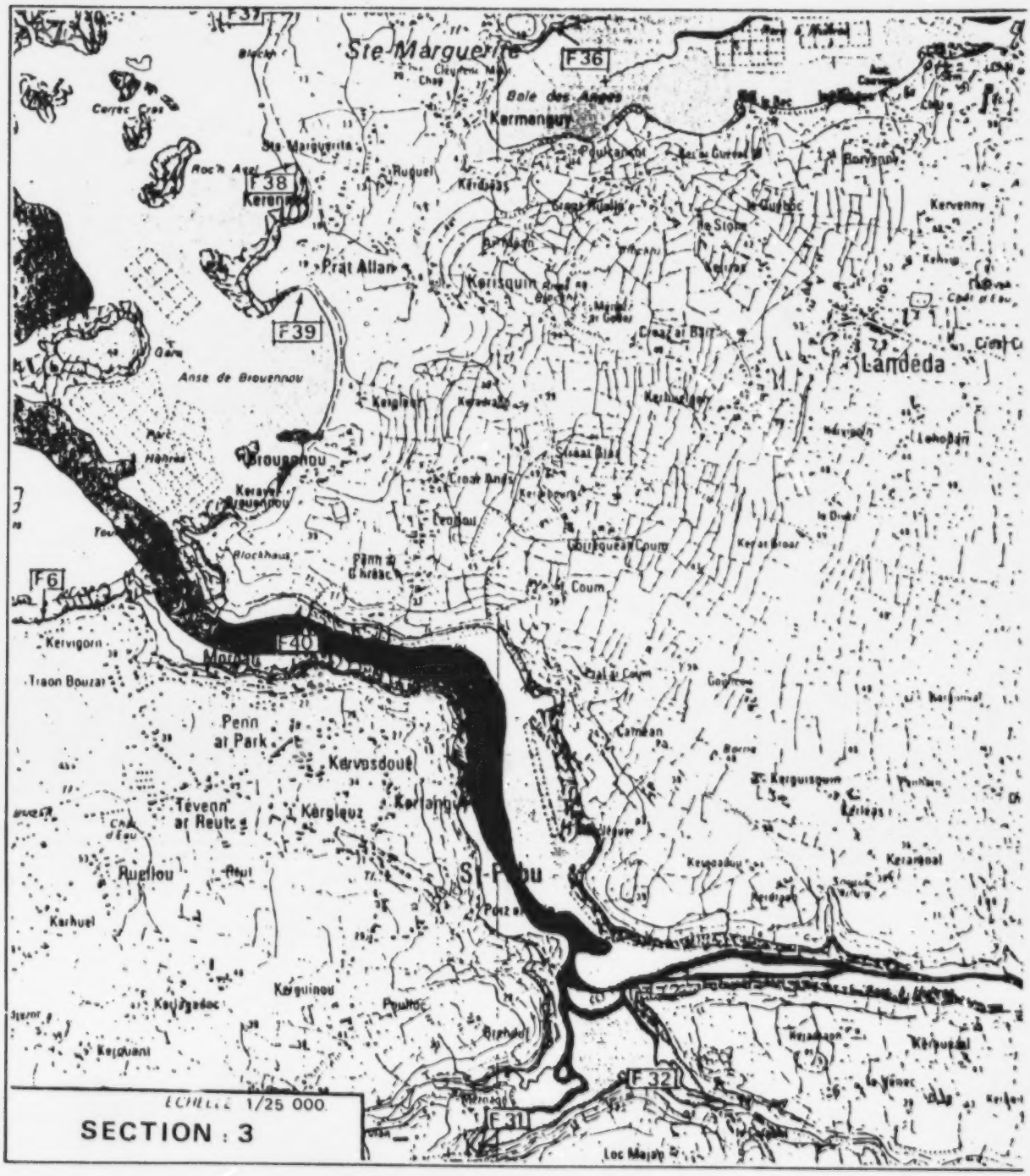
SUIVI DES STATIONS SECTION N° 2	ETAT DE POLLUTION { m : moyen p: propre F : fort f: faible	SURFACE	EAU INTERSTITIELLE	PROFONDEUR
2 FEVRIER 1979 Cette station a été revisitée à la suite d'une recontamination notable. Les laisses de haute mer étaient huileuses, mais la face de la plage etait propre, ainsi que l'eau interstitielle (sauf quelques traces en terrasse de basse mer). La couche interstratifiée a disparu. A la base des dunes, on distingue plusieurs horizons de pétrole interstratifié ayant échappé à l'érosion et, en surface, des plaques de pétrole induré de plusieurs centimètres d'épaisseur.		mf	f	f
2 MARS 1979 Les laisses de haute mer huileuses ont disparu, mais la pollution de la base des dunes demeure. L'eau interstielle est propre, sauf au niveau de la terrasse de basse mer où le pétrole s'est accumulé par lessivage.		fp	mf	fp
AMC 5 - DUNES DE TREOMPAN (Voir figure 4 et photographie n°12) Station très polluée à plusieurs reprises jusqu'en Avril 1978, elle a été revisitée en Février à la suite d'une nouvelle contamination.				
1° ET 2 FEVRIER 1979 Les grandes marées associées aux tempêtes de la fin Janvier ont porté très haut le pétrole ; le dépôt, d'un millimètre d'épaisseur, couvre 50% du haut de la plage sur une largeur de 3 mètres (soit environ 7 tonnes pour l'ensemble des dunes de TREOMPAN). L'interstratification (à -40cm en Juillet 78) a disparu, ce qui traduit un amaigrissement notable de la plage. Par contre, on trouve trois niveaux discontinus de pétrole interstratifié dans la base des dunes. Ces niveaux apparaissent en relief du fait de leur plus forte cohésion par rapport au sable propre. L'érosion des dunes est très marquée, avec effondrement de pans entiers. Le sable de la face de la plage est propre, mais couvert de nombreuses boules de pétrole. L'eau interstitielle est fortement polluée au niveau de la terrasse de basse mer.		m	m	fp
2 MARS 1979 La situation est inchangée par rapport au mois précédent à l'exception du haut de la plage où la fine couche déposée le 31 Janvier a disparu.		fp	m	p



-STATION AMC 5- Evolution entre mars 78 et février 79.

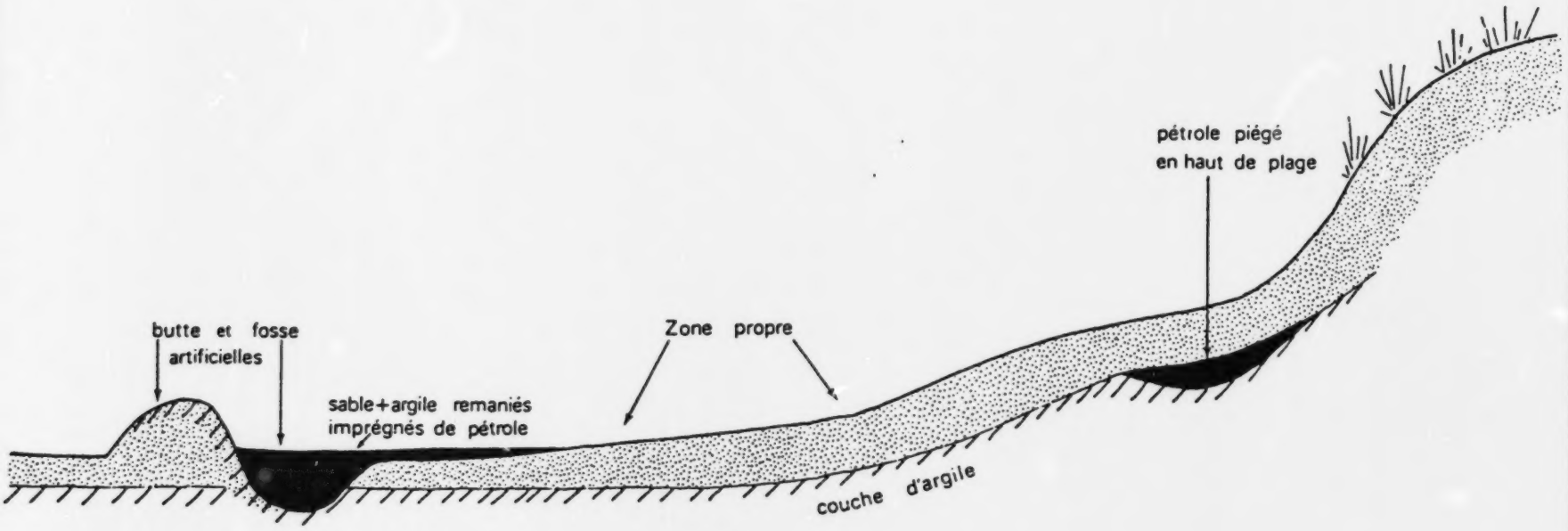


Oil distribution within l'Aber Benoit: (A) at Loc Majan, (B) Loc Majan to Treglonou, and (C) Treglonou to the head of the Aber (from preliminary report by D'Ozouville).


Ste-Marguerite
F36
Baie des Anges
Kermanguy
Ste Marguerite
Roc'h Ael
F38
Kerenn
Ruguel
Prat Allan
F39
Kerisquin
Landeda
Anse de Brouennou
Brouennou
Kervigorn
Traon Bouzar
F40
Penn ar Park
Kervasdoue
Tévenn ar Reuts
Kergleuz
Ruellou
Karhuel
Kerguinou
Kerguiani
Camaan
Kerguiscum
Keranneal
F32
F31
ECHELLE 1/25 000
SECTION : 3

SUIVI DES STATIONS SECTION N° 3	ETAT DE POLLUTION { m : moyen p: propre F : fort f: faible	SURFACE	EAU INTERSTITIELLE	PROFONDEUR
F6 - KERVIGORN				
7 MARS 1979		p	p	p
Le site, pollué en Mars 78, est entièrement propre.				
F 31 - LE GRAND MOULIN (ABER BENOIT)				
7 MARS 1979		m	F	F
La vase a piégé le pétrole qui s'était engouffré jusqu'au fond de l'estuaire ; la décontamination est très lente, mais la présence d'irrisations à la surface de l'eau traduit néanmoins un certain autonettoyage				
F 32 - LE CARPONT (ABER BENOIT)				
2 FEVRIER 1979		m	F	F
La station est très polluée (cf F31). On observe des irisations sur l'eau et le sédiment. Dans la partie haute, les plaques de pétrole induré sont nombreuses.				
7 MARS 1979		m	F	F
On n'observe pas de décontamination notable par rapport au mois précédent				
F 85 - PONT DE TREGLONOU (ABER BENOIT)				
7 MARS 1979		f	m	m
Cette station, très polluée en Mars 78, a bénéficié d'un nettoyage important. Les irisations de l'eau interstitielle sont moyennes à faible.				
F 40 - PEN AR CREAC'H				
Tres polluée en Mars 78, cette station était relativement propre en Juillet à l'exception de la partie supérieure de la berge.				
7 MARS 1979		m	m	m
La situation a peu évolué depuis Juillet 78 ; l'argile affleurant en haut de plage est partiellement couvert d'asphalte, par contre, la face de la plage est propre en surface ; immédiatement sous la surface, on trouve une couche polluée de 5 cm d'épaisseur.				
F 36 - PRESQU'ILE STE MARGUERITE				
Station extrêmement polluée en Mars 1978				
2 MARS 1979		p	m	m
La surface de la plage est propre, à l'exception du pied des dunes couvert de laisses de haute mer huileuses. Le phénomène est analogue à celui observé le mois précédent dans le même secteur (voir stations AMC 5 et AMC 11).				

SUIVI DES STATIONS SECTION N° 3	ETAT DE POLLUTION { m : moyen p: propre F : fort f: faible	SURFACE	EAU INTERSTITIELLE	PROFON-
A 54 cm de profondeur, on trouve une couche de pétrole interstratifié de 2 cm d'épaisseur. (partie supérieure de la plage).				
F 37 - PRESQU'ILE STE MARGUERITE Station très polluée en Mars 78, mais déjà nettoyée en surface en Juillet.				
2 MARS 1979 En haut de plage, on trouve des plaques d'asphalte sur l'argile affleurant. Les rochers sont encore pollués. La face de la plage est propre en surface, mais une couche de pétrole de 8 cm d'épaisseur est interstratifiée à 50 cm de profondeur. La terrasse de basse mer présente une eau interstitielle polluée.		m	m	m
AMC 11 - PRESQU'ILE STE MARGUERITE (Voir photographie 16 et figure 5) Station extrêmement polluée en Mars 1978.				
5 NOVEMBRE 1978 La face de la plage est propre en surface, mais on rencontre un horizon discontinu pollué à 50 cm de profondeur. Cet horizon a été bloqué par une couche d'argile. Au niveau de laterrasse de basse mer, la tranchée creusée au bulldozer pour pomper le pétrole a atteint la couche d'argile. Toute la zone ainsi remaniée demeure très polluée, l'argile extrait piégeant le pétrole. Là où l'argile n'a pas été remanié, la terrasse de basse mer est faiblement polluée, à l'exception des zones de rochers et de galets plus sales.		m	F	n
2 FEVRIER 1979 Par rapport à Novembre 78, le fait marquant est l'érosion qui affecte les dunes ; quelques laisses de pétrole sont déposées en haut de plage. On retrouve le niveau pollué discontinu à 42 cm de profondeur.		m	F	r
2 MARS 1979 Mêmes observations que le mois précédent, les laisses de pétrole ont disparu, le niveau pollué discontinu en haut de plage se retrouve à - 50 cm.		m	F	m
F 34 - PEN ENEZ Cette pointe rocheuse a été très polluée en Mars 78.				
2 MARS 1979 Les rochers sont propres ou faiblement pollués.		fp	-	-

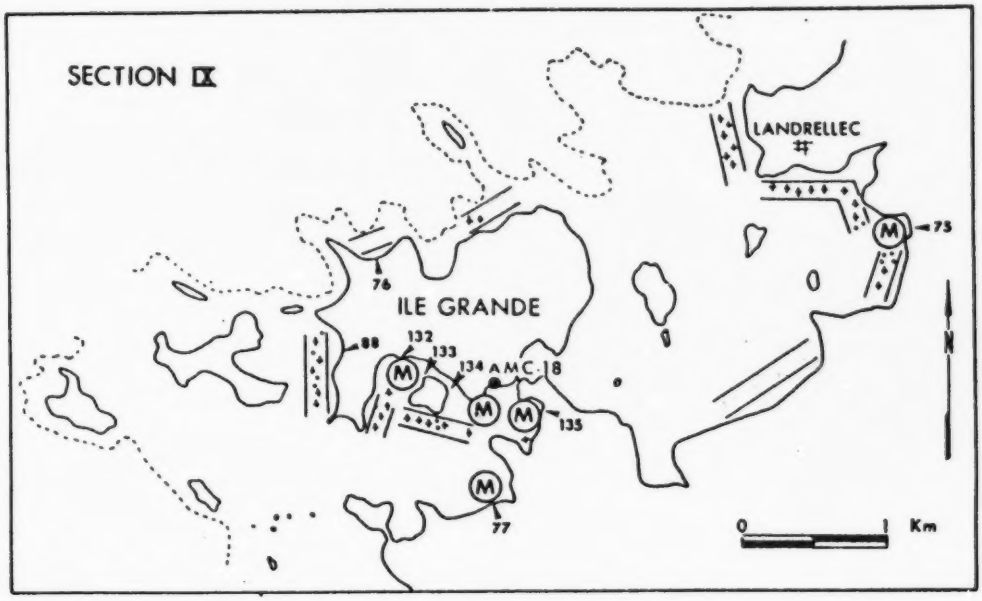


STATION AMC 11 - Etat en mars 79

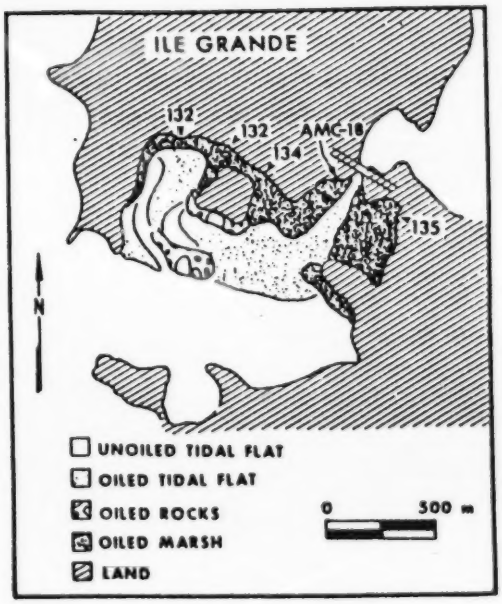
Field observations of oil distribution at stations of Section III, Les Dunes-East to the Plouguerneau peninsula.

Station Number	Date(s) Visited	Location and Type of Environment	Description of Oil Impact
F-6	20 Mar	Ker-Vigorn Mouth of estuary.	Oil boom deployed - no oil at this time - to become heavily oiled starting 21 March.
F-31	26 Mar	Grand Moulin Western arm of l'Aber Benoit; tidal flat (mud) with rocks along shore.	Very light sheen.
F-32	26 Mar	Le Carpont Arm of l'Aber Benoit; tidal flat.	Heavily oiled.
F-85	31 Mar	Treglonou Large fine-grained tidal flats.	Heavily oiled along shoreline.
F-40	26 Mar	l'Aber Benoit Entrance to estuary.	Boom in place.
F-39	26 Mar	Prat Allan Arcuate cobble beach.	Heavily oiled with a large oil pool offshore.
F-38	26 Mar- 22 Apr-	Presqu'ile Ste. Margarite Coarse-sand pocket beach.	-heavily oiled. -oil burial 70 cm and 35 cm with light swashes on surfaces.
F-37	26 Mar	Presqu'ile Ste. Margarite Coarse-sand pocket beach.	Heavily oiled.
AMC-11	26 Mar- 1 Apr- 22 Apr-	les Dunes de Ste. Margarite Medium-sand pocket beach backed by eroding dune scarp.	-heavily oiled; extensive clean-up operation with manpower, front-end loaders, and backhoes. -heavily oiled upper berm; front-end loader removing oiled sand. -95% cleaned; some minor burial.
F-33	26 Mar	South of Penn Enez Sand pocket beach.	Heavily oiled.
F-34	26 Mar	Penn Enez Boulders in front of small scarp beach.	60 m - heavily oiled.
F-35	26 Mar	Penn Enez (East side) Small pocket beach.	Moderate oiling.
F-36	26 Mar	Poullac Harbor Wide exposed sand flat.	No oil.

SUIVI DES STATIONS SECTION N° 8	ETAT DE POLLUTION { m : moyen p: propre F : fort f: faible	SURFACE	EAU INTERSTITIELLE	PROFONDEUR
F 141 - POINTE DE PLESTIN Cette station n'a été que très faiblement touchée (elle se rattache en fait à la zone LOCQUIREC-POINTE D'ARMORIQUE de la station 7) 8 MARS 1979 Le site est entièrement propre		p	p	p
F 53 - LES CARRIERES ST EFFLAM Cette station a été moins touchée que celles situées immédiatement à l'Est. 8 MARS 1979 Le site est entièrement propre en surface, l'eau interstitielle est cependant polluée au niveau de la terrasse de basse mer.		p	f	p
F 54 - PLESTIN LES GREVES Cette station a été fortement touchée en Mars et Avril 78 ; on y a enregistré des mortalités très importantes de bivalves et d'oursins 8 MARS 1979 La plage et la terrasse de basse mer sableuses sont entièrement propres ; seuls les galets en haut de plage sont localement pollués. Au Nord du ruisseau "LE ROSCOAT", une plaque de galets fortement pollués demeure.		fp	p	fp
AMC 19 - ST MICHEL EN GREVES Station très polluée en Mars 78, avec de très fortes mortalités observées. 7 MARS 1979 Les laisse de haute mer sont légèrement polluées ; la plage est propre en surface, mais on retrouve à -10 ou -15cm sous la surface une couche polluée.		fp	f	m
AMC 15 - ST MICHEL EN GREVES Station extrêmement polluée en Mars 78; en Juillet 78, on observait encore du pétrole enfoui, mais la surface était propre. 7 MARS 1979 La plage est propre en surface et en profondeur ; par contre, la terrasse de basse mer présente un horizon pollué à 5 cm sous la surface et l'eau interstitielle est irrisée.		p	f	mf



Locations of observation stations in Section IX. Oil coverage for the second study period is indicated as follows: heavy oiling--pluses, light oiling--dot pattern, and oiled marshes--circled M's.



The Ile Grande marsh area observation stations and oil distribution on the tidal flat and marsh.

SUIVI DES STATIONS SECTION N° 9	ETAT DE POLLUTION { m : moyen p: propre F : fort f: faible	SURFACE	EAU INTERSTITIELLE	PROFONDEUR
F 78 - KERHELLEN Station très polluée en Mars 78 ; En Avril, on observait un enfouissement en haut de la plage 7 MARS 1979 Le site est entièrement propre		p	p	p
F 77 - RUNIGOU Station très polluée en Mars 78, en Avril, la pollution était surtout forte en haut de plage 7 MARS 1979 Les rochers en haut de plage sont très pollués, on trouve également des épaisses plaques d'hydrocarbures sur le sable. La terrasse sableuse est propre en surface, mais on trouve, bloqué sur la couche d'argile, un niveau pollué interstratifié à 2 cm sous la surface, épais de 4 cm. L'eau interstitielle est fortement polluée.		mF	mF	mF
F 135 - ILE GRANDE - ALLEE COUVERTE Le marais avait été entièrement détruit par le pétrole 4 NOVEMBRE 1978 La partie la plus touchée du marais a été décapée à la pelle mécanique et remblayée par un mélange de terre et de cailloutis. Dans la partie non remaniée, on observe que : - La partie basse du marais (à SESUVIUM) est entièrement détruite - La partie supérieure (JUNCUS) n'est que partiellement détruite - Un léger processus d'auto-nettoyage par les chenaux est en cours		F	F	F
7 MARS 1979 Peu d'évolution		F	F	F
AMC 18 - PONT DE L'ILE GRANDE (Voir photographies 18 et 19) Le marais a été extrêmement pollué en Mars 78 4 NOVEMBRE 1978 Le marais est encore extrêmement pollué : - La partie haute du marais (flore à JUNCUS) est partiellement couverte d'asphalte, mais la végétation demeure vivante - L'étage inférieur (flore à SESUVIUM) est détruit à 95%, il n'y a pas de reprise notable de la végétation		F	F	F

Field observations of oil distribution at stations of Section IX, the Ile Grande area.

Station Number	Date(s) Visited	Location and Type of Environment	Description of Oil Impact
F-77	31 Mar-	Runigou	-heavily oiled.
	25 Apr-	A sand flat with a rip-rap wall along the sides of the flat. A small marsh is also in the area.	-sand flat all clean; rip-rap wall still heavily oiled; marsh remains moderately oiled.
F-135	25 Apr-	Allée Couverte South side of Ile Grande Marsh; vegetation mainly Juncus marsh grass.	-very heavily oiled, cleanup operation in progress; 5 cm of oil on much of the marsh; soldiers using squeegees to push the oil into the channels where it is being pumped out.
AMC-18	29 Mar-	Ile Grande Marsh, and west side of D21 bridge to Ile Grande Large marsh with a wide, muddy sand channel.	-very heavily oiled; oil pools to 27 cm deep; average coverage about 3 cm; thousands of polychaetes worms crawling over the surface of the oil to escape.
	2 Apr-		-oil in same condition; polychaetes all dead and often found in small water pools on the surface of the oil.
	24 Apr-		-visit at hightide; only a light sheen visible on water surface.
	25 Apr-		-area has been manually cleaned; large oil pools drained; marsh still very black but some new green grass shoots appearing.
F-134	25 Apr-	West Road to Rulosquet Part of Ile Grande Marsh area.	-area oiled; extensive clean-up operation underway: light sprinkler system rinsing the marsh as well as high-pressure hosing.
F-133	25 Apr-	East Road to Rulosquet Part of Ile Grande Marsh area.	-still completely oiled; many trenches dug to drain oil; blackened; large clean-up underway.
F-132	25 Apr-	Dourlin Western side of Ile Grande Marsh--a narrow fringing marsh beside a sand flat.	-section 20 m wide remains thinly oiled after clean-up; numerous tire tracks, ditches, trenches on the sand flat as a result of clean-up.
F-88	2 Apr-	Ile Grande Beach (East Facing)	-heavily oiled.
	25 Apr-	Sheltered sandy pocket beach; wave energy usually low due to an island directly offshore.	-heavily oiled shoreline and tidal flat.
F-76	29 Mar-	Northwest Ile Grande Boulder beach.	-lightly oiled boulder beach.
	25 Apr-		-light oil coverage on boulders.
F-75	29 Mar-	(Near) Kerenoc	-small marsh and rocks heavily oiled.
	25 Apr-	Small marsh in northeast corner of large sand flat, with some rocks.	-very heavily oiled marsh grasses; some rocks with algae are completely oil covered; a large trench, dug to collect oil, causes serious oiling of the surface of the tidal flat.

SUIVI DES STATIONS SECTION N° 9	ETAT DE POLLUTION { m : moyen p: propre F : fort f: faible	SURFACE	EAU INTERSTITIELLE	PROFONDEUR
sous la surface au niveau de la terrasse, à 20 cm en haut de plage. L'eau interstitielle de la terrasse de basse mer est très polluée.				
F 76 - TOUL AR STAON Cette pointe rocheuse a été peu touchée. 6 MARS 1979 Les rochers sont légèrement pollués dans les parties abritées.		f	-	-
F 75 - KERENOC Le marais et les rochers ont été extrêmement pollués en Mars 78. 4 NOVEMBRE 1978 Cette station très abritée demeure extrêmement polluée; dans la partie supérieure du marais, les végétaux, morts, sont couverts de plaques d'asphalte ; le sable grossier, également couvert partiellement d'asphalte, recèle à -10cm de profondeur un horizon très pollué ; l'eau interstitielle est couverte d'une épaisse couche brune d'hydrocarbures. L'usage de moyens lourds pour nettoyer la terrasse de basse mer a contribué à l'enfouissement du pétrole. La tranchée creusée en Mars-Avril pour pomper les hydrocarbures fonctionne comme un piège à pétrole. 6 MARS 1979 Il y a très peu d'évolution par rapport à Novembre.		F F	F F	: F
F 204 - LANDRELLEC (NOUVELLE STATION) 6 MARS 1979 Les rochers sont encore pollués mais le sable est propre.		m	f	p

APPENDIX E - PHOTOGRAPHS

Photo/Slide Nos.	
1	Site A: Treompon (23-3-85) Wide, medium-coarse grained sand beach. Arrow indicates tractor that is harvesting seaweed.
2	Site B: Aber Benoit, near Loc Majan (23-3-85) Sample Site 1 - SHWM (located by B. Long) Sample Site 2 - NHWM (located by W. Robson)
	Site C: Aber Benoit, near Croix
3	View of highest level - B. Long at MHWM
4	Sample 6 - at NHWM - marked by scale
5	Sample sites 4 and 5 - NHWM
6	Sample 3 - part of 'latex-type' oil mat
7	Close-up of sample site 6
8	Detail of sample 6 with green vegetation lifted to show anerobic (black) subsurface
	Site D: Toenot (23-3-85)
9	Sample 33 - approx. 1.0 m below SHWM
10	Sample 35 - approx. 1.5 m below SHWM
11	Sample 36 - approx. 1.5 m below SHWM
	Site E: Ile Grande Marsh (24-3-85)
12	Location #1, area of sample 9 NHWM
13	View from location #3 north towards Location #1
14	Close-up of oil on marsh surface at Location #1

15 Close up of eroding marsh edge with oil on surface at Location #1

16 Location #8: scale is at samples 23, 29 and 31 on marsh surface; bag is at samples 24 and 25

17 Close-up of site for samples 23 (surface) and 29 and 31 (subsurface)

18 Samples 26, 27 and 28 collected from creek edge - approx. 2.0 m lower in elevation than samples 23, 29 and 31

19 Sample 10 being collected from location #2 at low tide

20 Close-up of sample 10

21 Location #6, degraded marsh surface, formerly Juncus zone

22 Site of samples 21 and 22 at edge of small creek in the area of location #6

23 Close-up of sample 22

24 Vehicle tracks in former mature marsh area - location #7

25 Similar to photo 24

26 Bulldozer tracks in asphalt pavement just to the east of location #8

27 Location #3 - site of samples 11 through 15

28 Sample 13 at SHWM

29 Area of samples 12 and 15, 0.5 m below SHWM

30 Sample 11, 1.0 m below SHWM

31 From location #4 looking northeast across towards Location #3

32 Sample 16 at location #4, 1.0 m below SHWM

33 Sample 17, location #5

34 Sample 17

35 Oil with fresh appearance at location #5

36 Sample 19, collected from tar-like site at location #5.

Site F: Ile Grande - Point de Toul-ar-Staon (24-3-85)

37 Upper beach of pebble-cobble-boulder - figure at right near storm-ridge crest, some oil stains indicated by arrows

38 View landward from rock platform in lower intertidal zone - beach is approx. 20 m in elevation from low-tide rock platform to storm ridge crest

39 Small area of asphalt pavement on storm crest - sample 32

Site G: St. Michel en Greves (24-3-85)

40 Wide, flat fine-grained sand beach banked by steep pebble beach

41 East end of beach at low-tide.

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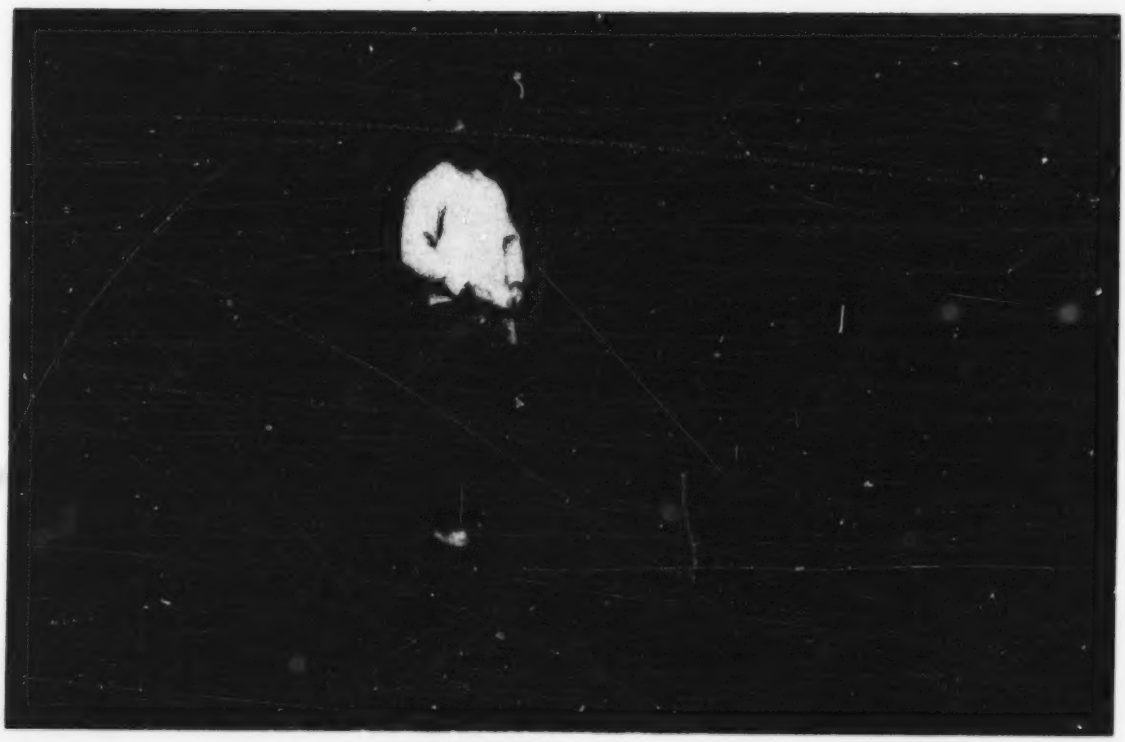

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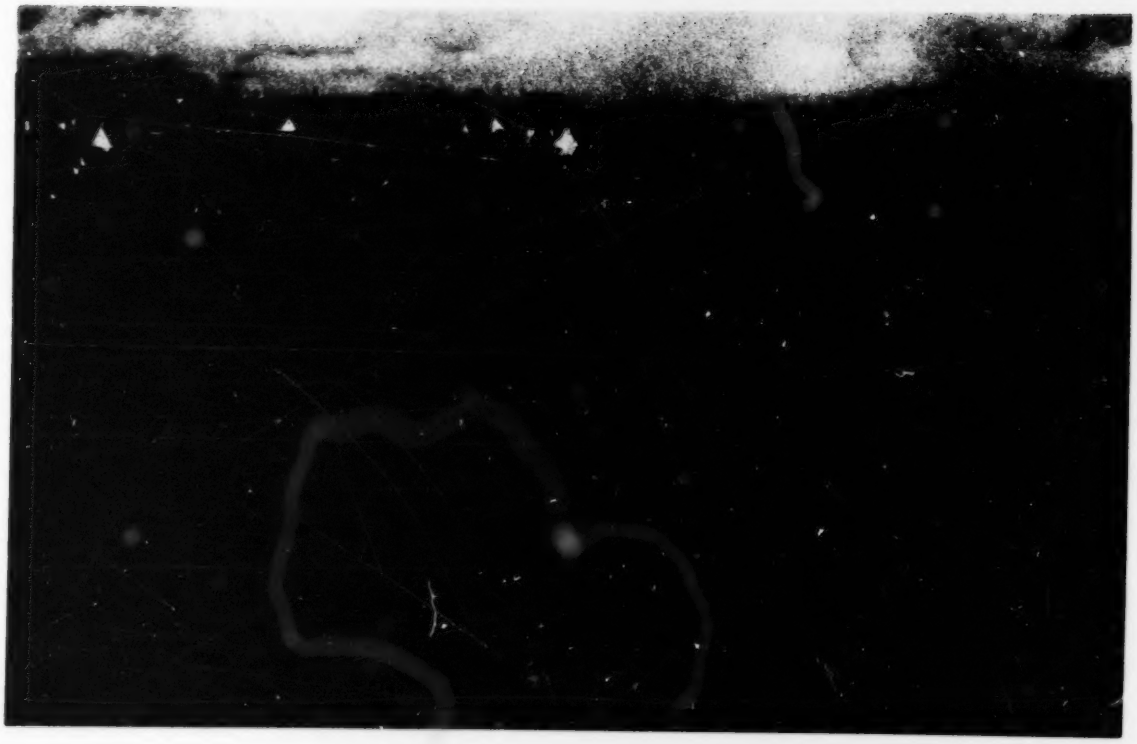
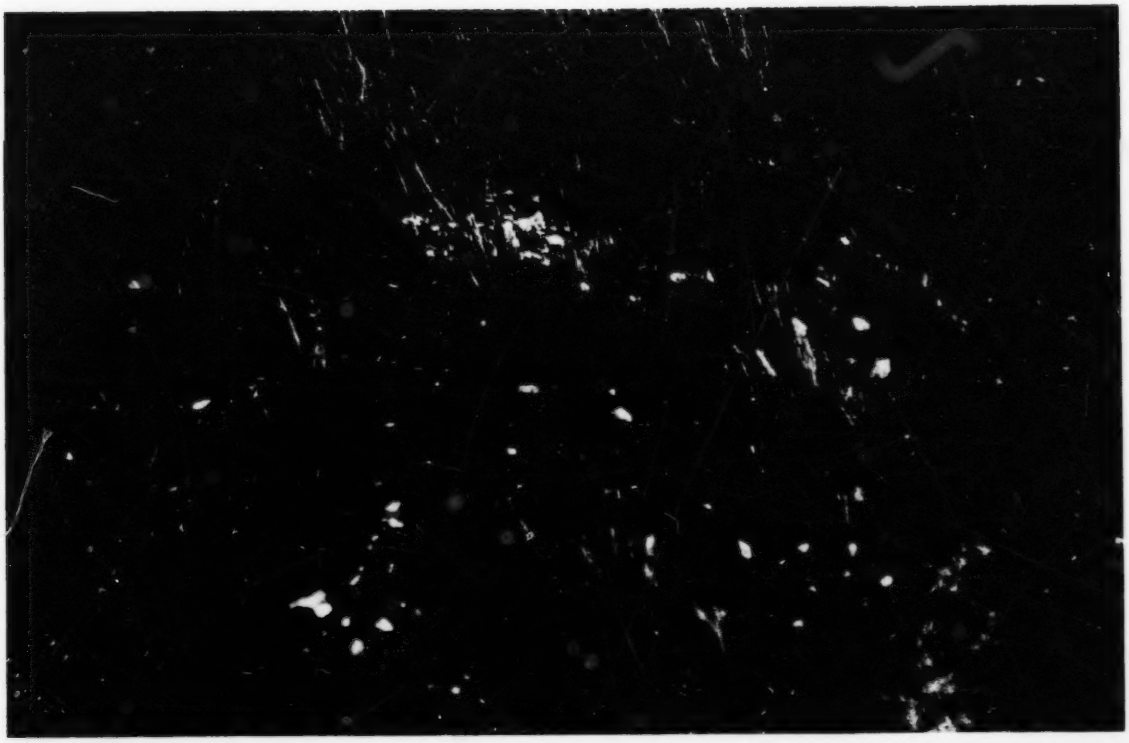


14.



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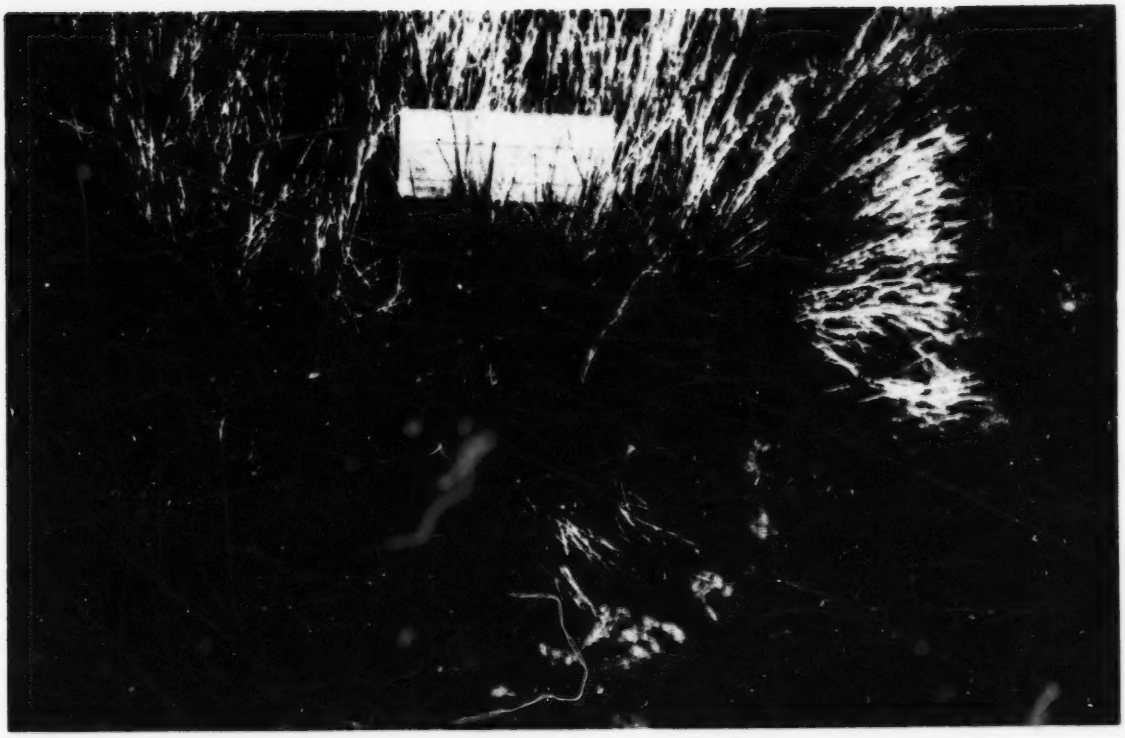

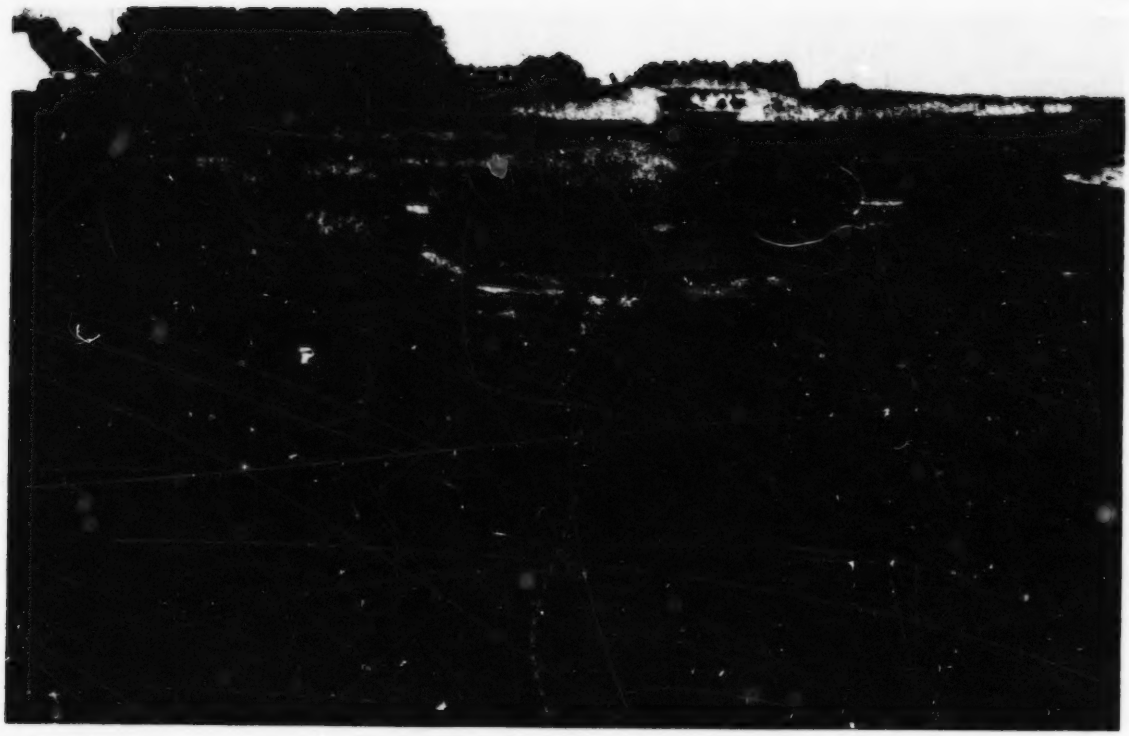

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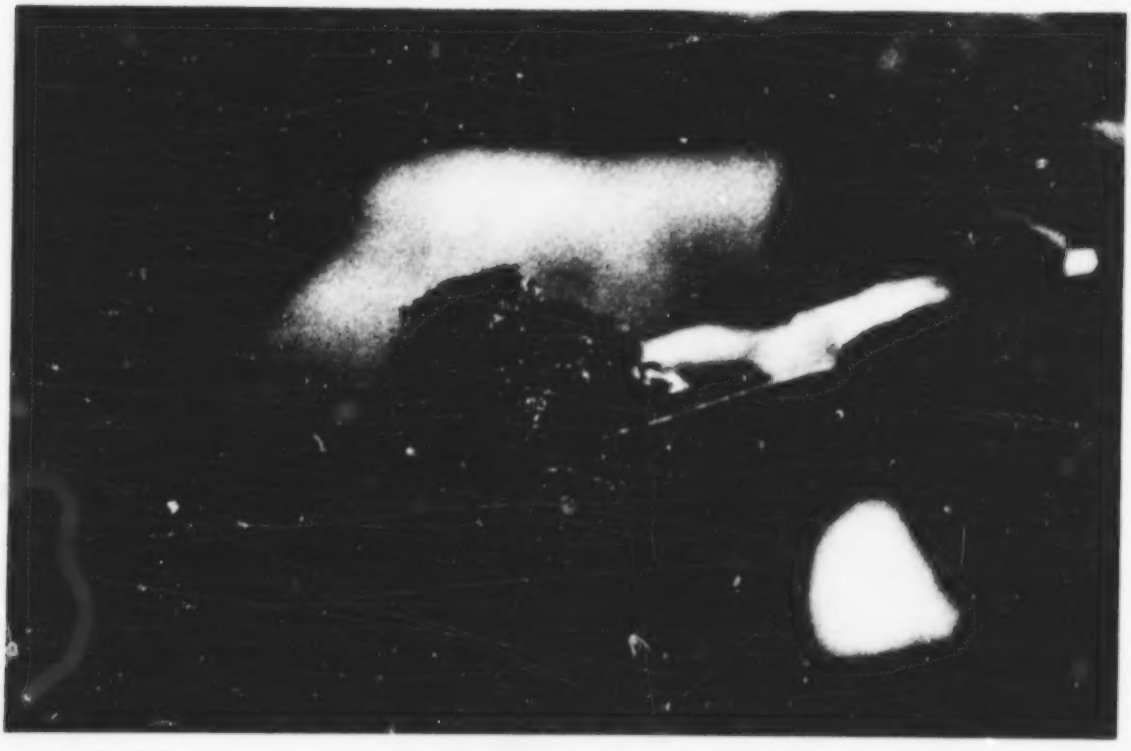

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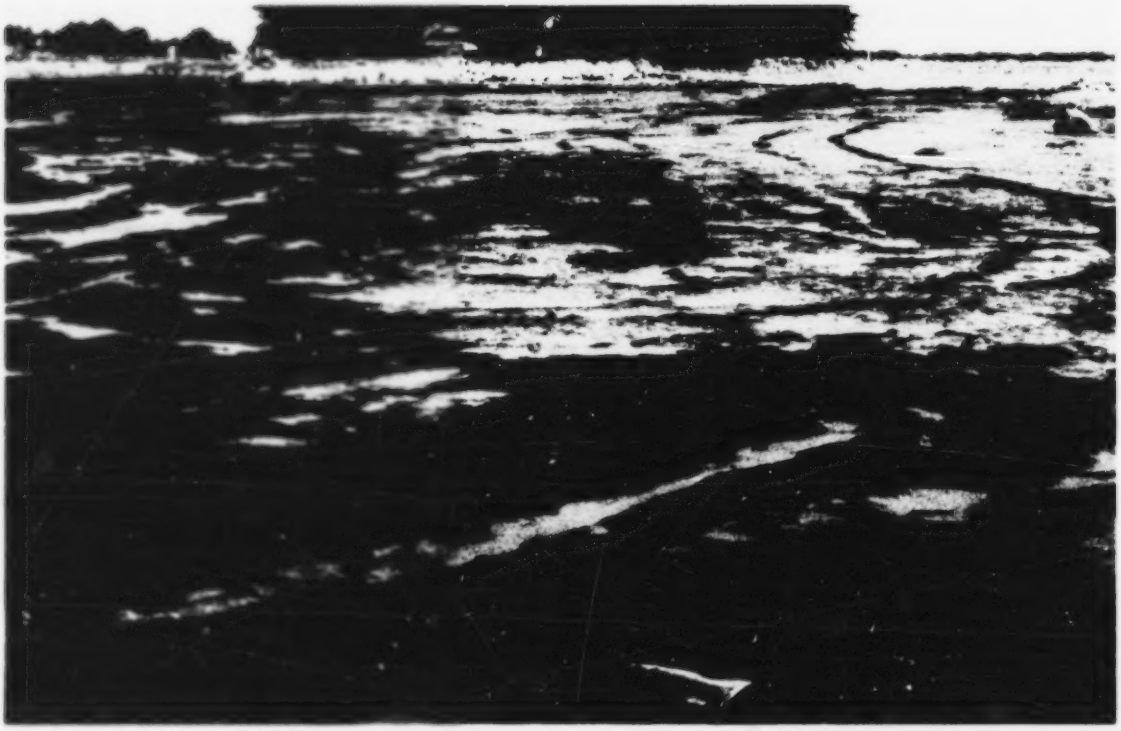

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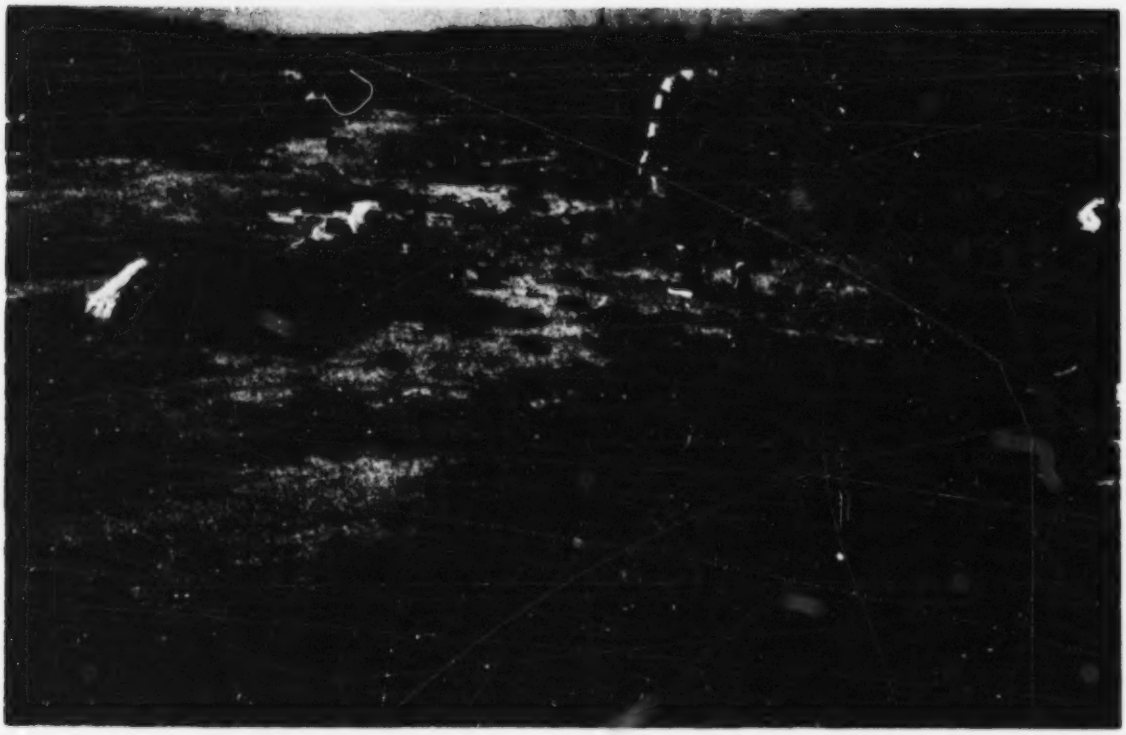

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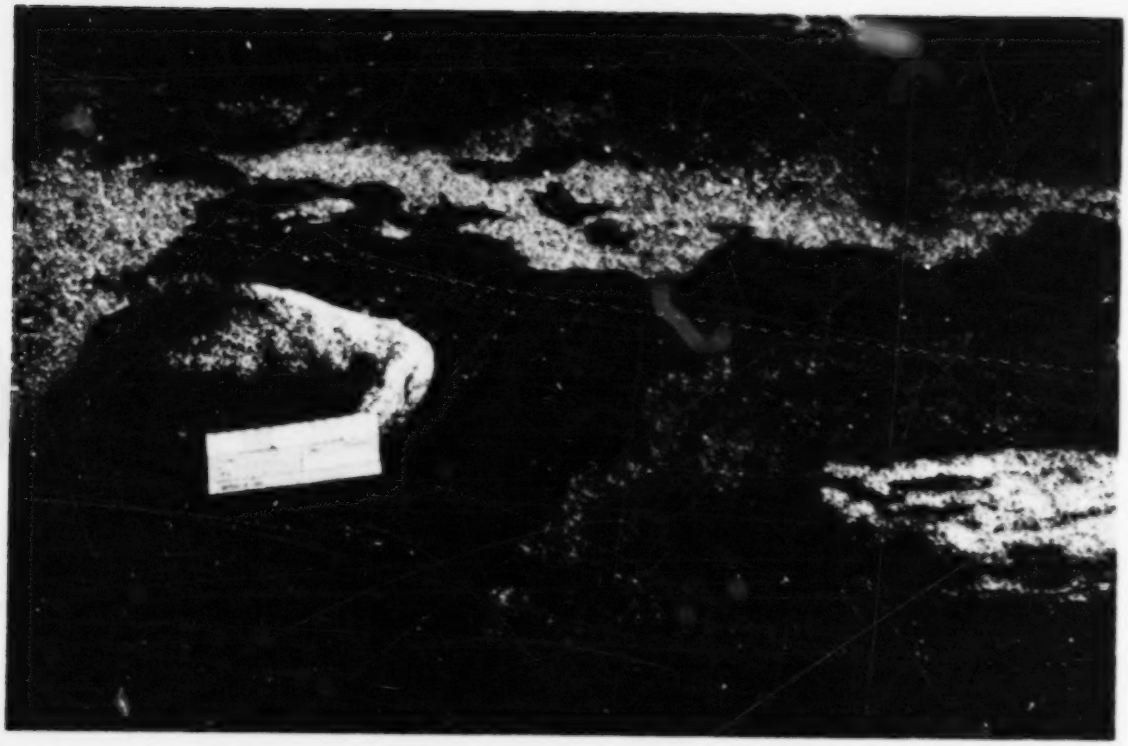

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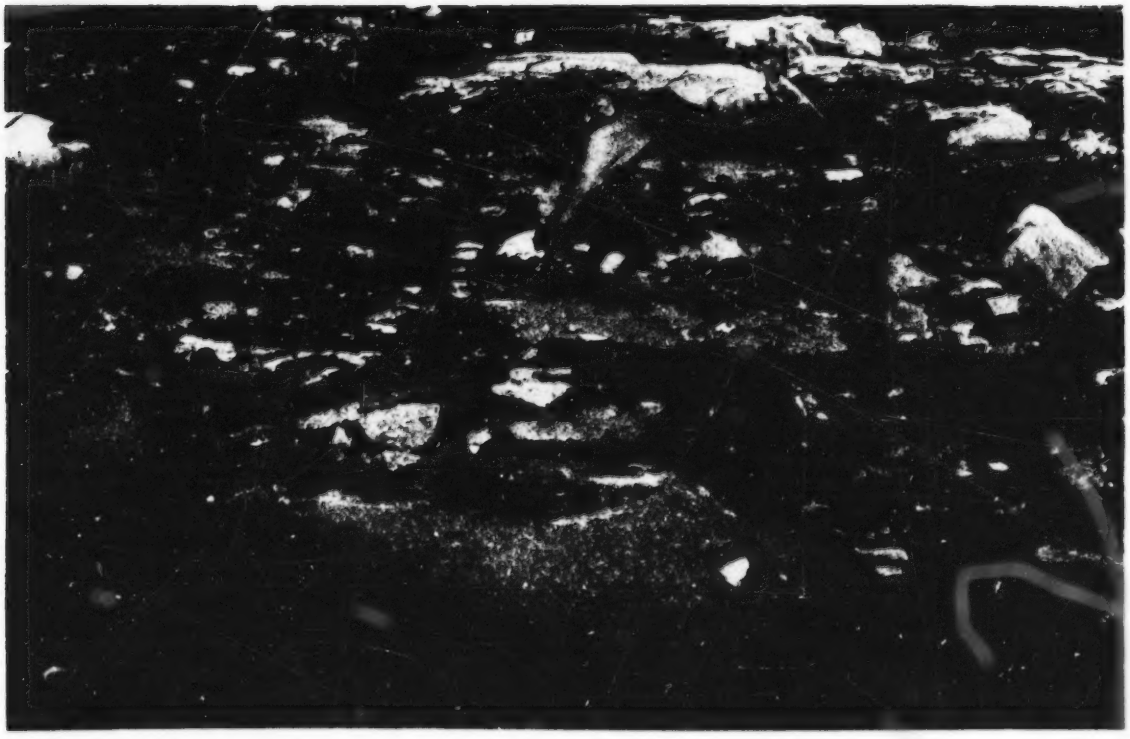

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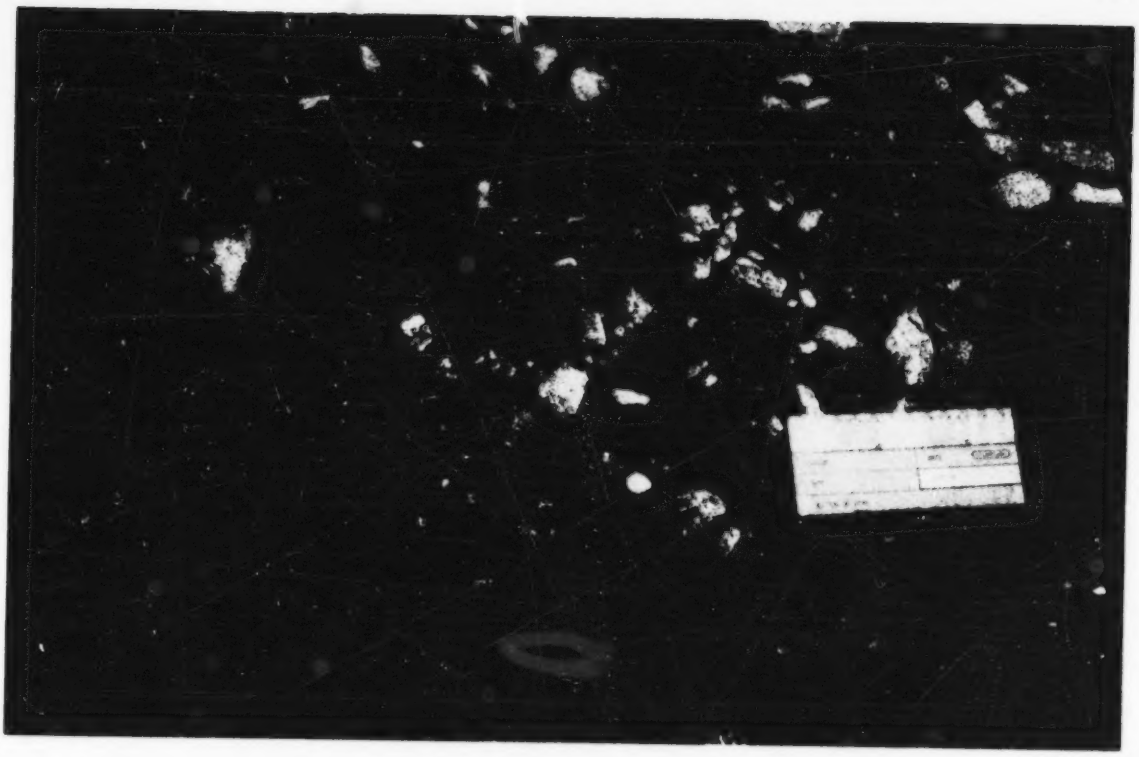

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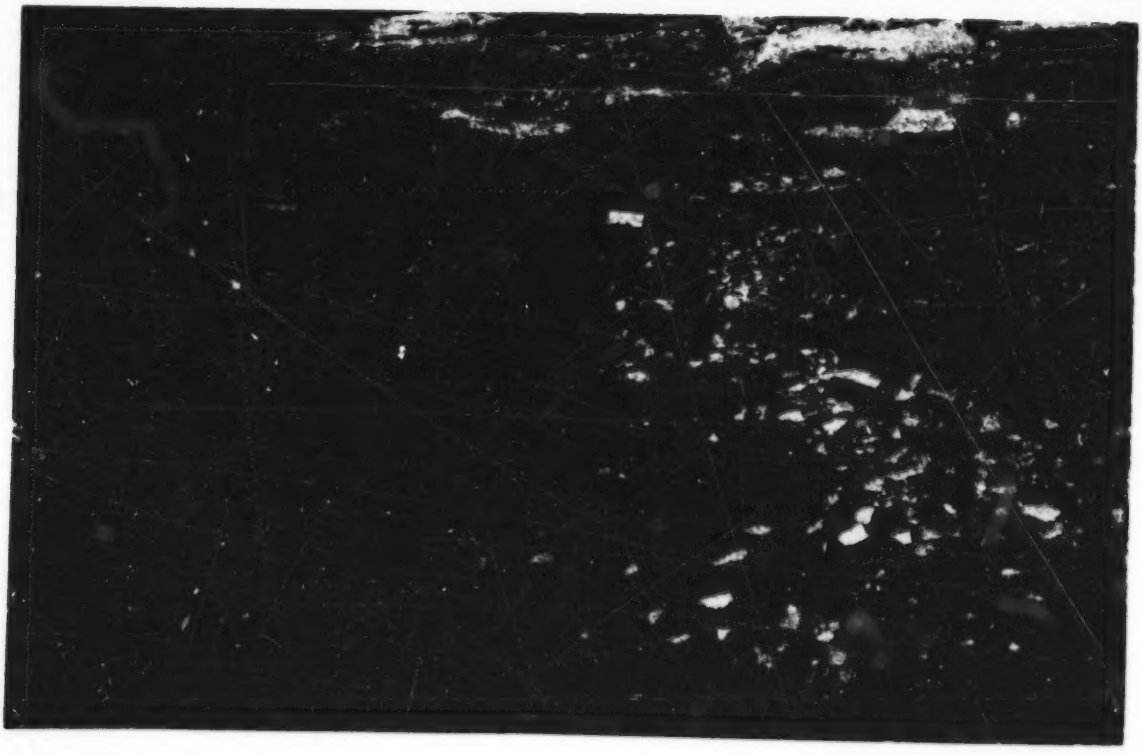

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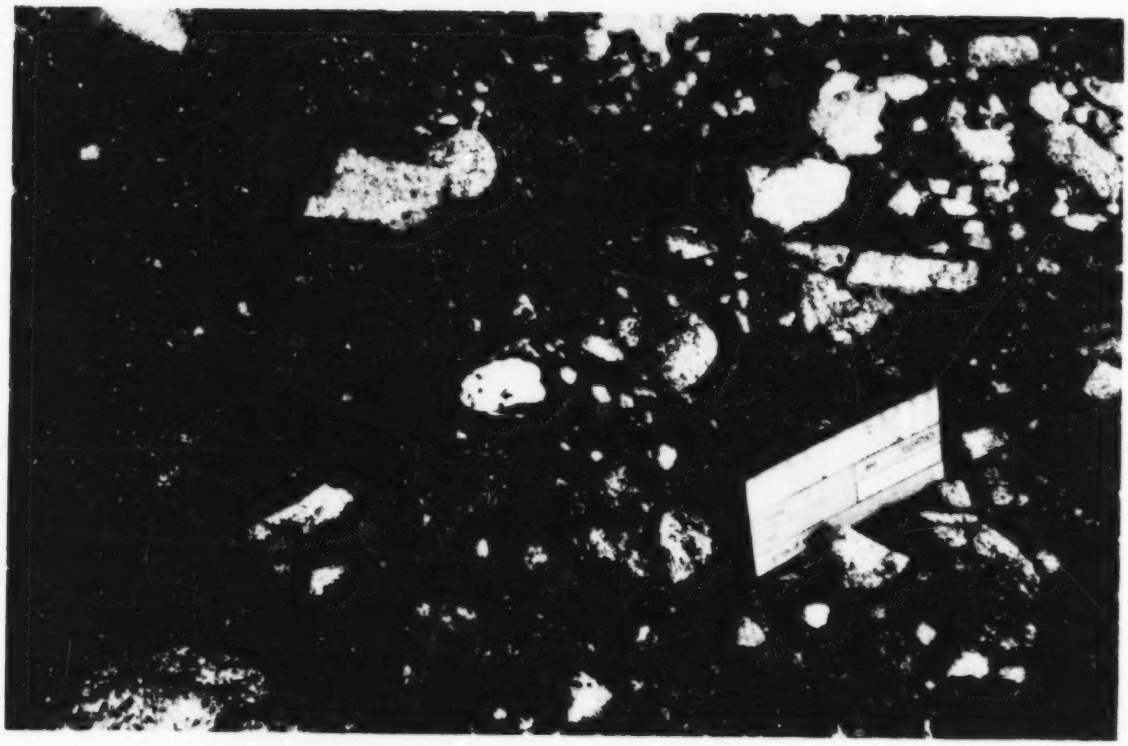

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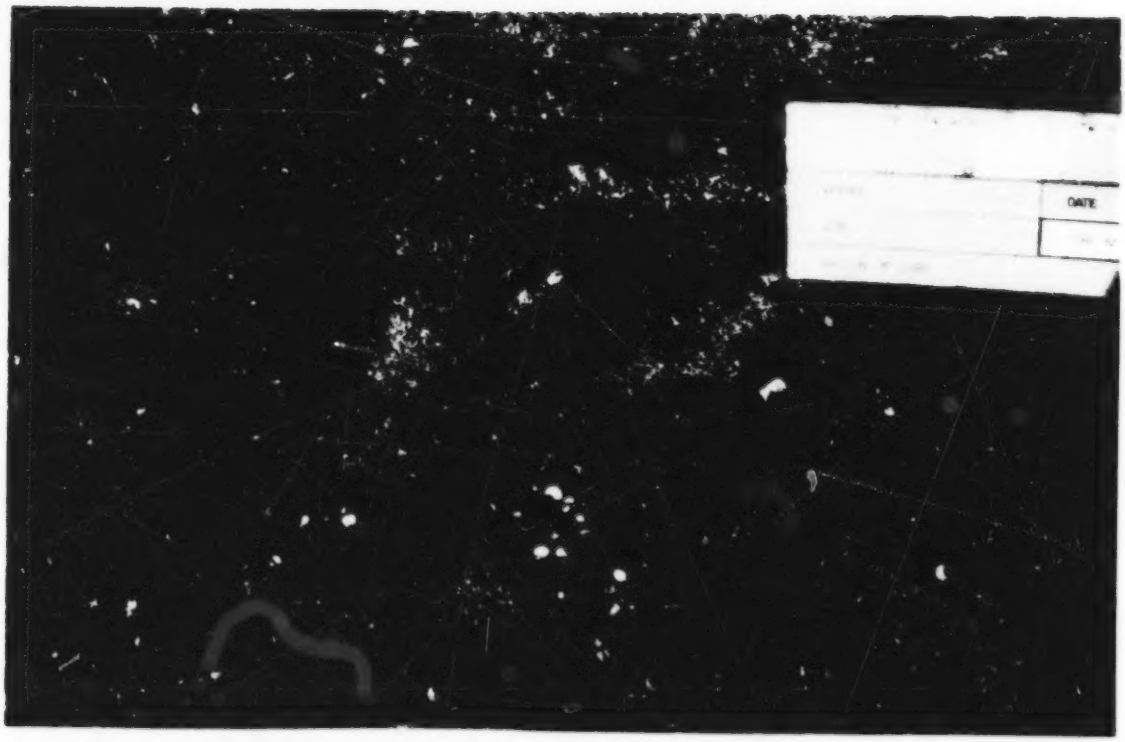

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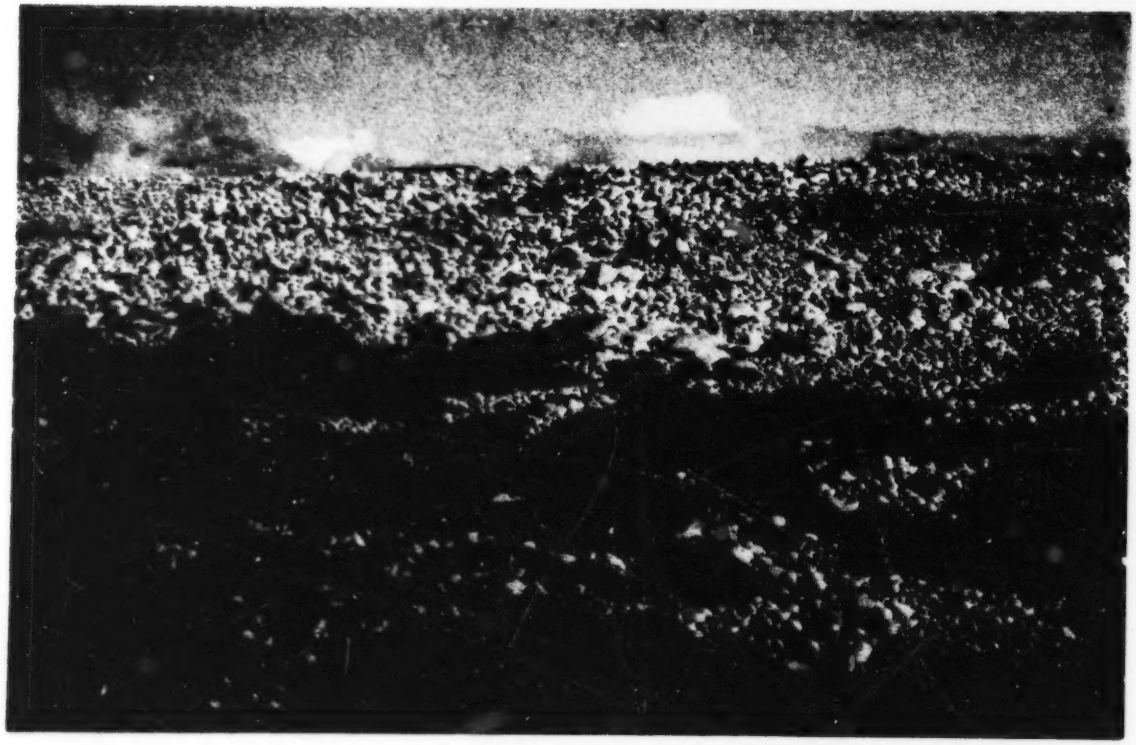

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